THE DIFFUSION OF HIGH YIELDING VARIETIES OF RICE IN BANGLADESH

by

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D E C L A R A T I O N

Except where otherwise indicated, this dissertation is my own work.

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A B S T R A C T

In the face of a chronic food grain shortage, the Government of Bangladesh has, since the late sixties, been trying to increase the domestic production of rice by introducing HYV rice. The First Five Year Plan (1973-78) of Bangladesh spelled out that by the terminal year, the country would be made self-sufficient in food grain production with the help of HYV rice. As it has turned out, the rate of adoption of HYV rice is much slower than anticipated. The rice self-sufficiency program depends on how rapidly HYV rice is being diffused by the farmers.

In this study, an effort has been made to look into the diffusion process of HYV rice in Bandladesh. Both the tabular and graphic surveys of data show diffusion to be at an early stage. Multiple regression has been used to isolate the factors which are important at the early stage of diffusion. Within the model we also tried to test for the relative importance of the various factors in the process.

It has been shown that the dissemination of information, along with improved availability of supplementary inputs like fertiliser, is likely to accelerate the rate of diffusion at the early stage.

On the basis of the results obtained, conclusions were drawn about how the rate of diffusion can be accelerated by government policy changes.

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CHAPTER 1

INTRODUCTION

1.1 The Problem

In recent years Bangladesh has been experiencing a shortage in food grain supply. Supply of foodgrains fluctuates from year to year depending on climatic and other factors. Rice is the principal foodgrain consumed in Bangladesh and shortages of foodgrain supply have been met either by imports or overseas grants. The lag between domestic production and demand for rice creates a profound impact on the movement of foodgrain prices and this, in turn, affects the general price level in the country. Rice is the principal component of an average consumer's budget and the fluctuations in rice price essentially dictate his overall consumption pattern with considerable welfare implications for consumers.

The foodgrain problem is primarily one-dimensional in Bangladesh, i.e., it is a production problem. Land, the most important factor in the agricultural production mix, is in limited supply. Theoretically, an increasing population may be faced with a given level of technology and fixed supply of land. Any increase in population, unless accompanied by the introduction of new agricultural technology, will lead to diminishing marginal returns from labour.

Economic development presupposes an increase in income level, and with rising incomes people will tend to consume more food - particularly higher quality, more expensive foods, which may require greater agricultural resources for their production. Increased demand for food will definitely imply that a certain portion of this increased demand will be for more foodgrain also. It is generally agreed that the income elasticity of demand for food decreases greatly as the level of income increases.

Foodgrain self-sufficiency or, for that matter, rice self-sufficiency is a crucial factor for planners in Bangladesh. In the context of both long-run and short-run planning for economic development, planners will have to make available basic minimum requirements per capita of foodgrain at a reasonable price, keeping in view the income level.

The recent trend in rice production in Bangladesh has been marked by consistent efforts on the part of the government to attain self-sufficiency in rice production to ease the foodgrain situation. The annual average growth rate of rice production in the 1950s was 0.7 per cent as against the population growth rate of 3 per cent per annum. The average growth rate of rice production had gone up to 2.5 per cent during the 1960s - population growth rate remaining at 3 per cent per annum. The increase in the growth rate of rice production in the 1960s did little to ease the foodgrain situation. If we look at the foodgrain import figures in Table 1.1, it will be apparent that in spite of the fact that growth of rice production has gone up during the 1960s, foodgrain imports have increased at a faster rate during the 1960s than in the 1950s.

During the 1960s more wheat than rice was imported into Bangladesh to substitute for rice as a foodgrain since the price of wheat was lower. But given a preferance, people will choose to have rice rather than wheat as a staple.

Low levels of production resulted in a deficit of foodgrains of 4.36 million tons in 1971-72, 1.9 million tons in 1972-73 and 2.2 million tons in 1973-74. The entire deficit had to be met by either imports or overseas foodgrain grants. The increase in foodgrain imports did not improve the per capita availability of foodgrain. This can be seen from Table 1.2.

TABLE 1.1

IMPORT OF FOODGRAIN INTO BANGLADESH
(in tons)

Year	Wheat	Rice	Total
1956	51,000	533,000	584,000
1957	75,000	432,000	507,000
1958	136,000	464,000	600,000
1959	161,000	473,000	634,000
1960	176,000	402,000	578,000
1961	187,000	357,000	544,000
1962	512,000	270,000	782,000
1963	919,000	565,000	1,484,000
1964	219,000	233,000	452,000
1965	892,000	191,000	981,000
1966	417,000	415,000	832,000
1967	789,000	361,000	1,150,000
1968	820,000	152,000	972,000
1969	958,000	311,000	1,269,000
1970	878,000	382,000	1,280,000

Source: G.O.B. (1972), Statistical Digest of Bangladesh No.8, p.158.

TABLE 1.2

PER CAPITA AVAILABILITY OF FOODGRAIN
FOR CONSUMPTION IN BANGLADESH

Year	Per capita availability (ounces per day)
1960-61	16.0
1961-62	15.6
1962-63	15.2
1963-64	16.2
1964-65	15.7
1965-66	15.6
1966-67	14.2
1967-68	15.2
1968-69	15.6
1969-70	16.4
1970-71	15.3
1971-72 (est.)	14.3
1972-73 (proj.)	15.1

Source: E. Sailer (1972), Report on the Mission of High Level United Nations' Consultants to Bangladesh, Vol.II.

1.2 Recent Efforts to Overcome the Problem and Their Outcome

A sense of urgency has always been observed in Bangladesh but the systematic endeavour for rice self-sufficiency started around the late sixties to tide over the increased demand for rice due to the increase in population. Comprehensive foodgrain self-sufficiency programs were adopted and updated regularly during the period with the aim of achieving foodgrain self-sufficiency by the year 1969-70, but the achievement fell far short of expectation. However, it did help to increase the level of Boro rice production from 830,000 tons in the year 1966-67 to 18 million tons in 1969-70.

The first Five-year Plan (1973-78) of Bangladesh spelled out in specific terms that by the terminal year of the Plan, i.e. 1977-78, the country would be made self-sufficient in foodgrain production. The early years of the plan's performance give a reasonable amount of doubt about achievement of the planned target.

One factor yas been found common in both the foodgrain self-sufficiency programs. Plans have banked on increased production from increased yields from HYV rice, with package inputs like fertiliser, credit and irrigation.

The current foodgrain self-sufficiency program under the first Five Year Plan estimates that foodgrain production will go up to 15.4 million tons from 11.3 million tons during the plan period and if it is possible to reach the target, it will indicate a cumulative growth of 36 per cent over the plan period. This target production will ensure foodgrain self-sufficiency at the terminal year on the assumption of per capita daily availability of 16 oz of foodgrain.

The method spelled out to achieve this target production of rice under the plan period is based on the assumption that the increased yield will be achieved by introducing HYV rice in the irrigated areas, selected rainfed areas and in the traditionally irrigated Boro areas. In quantitative terms, the planners estimated that 19.12 per cent of the total area under rice would belong to HYV rice, and HYV rice will contribute 31.17 per cent of the total rice production in 1973-74. By the terminal year 38.64 per cent of the area under rice would belong to HYV rice and it will contribute 59.58 per cent of the total production.

In spite of government efforts to raise the level of production of rice through introduction of HYV rice from the late sixties, Bangladesh is still far behind many Asian countries in adopting HYV rice. Table 1.3 gives an indication of the rate of adoption of HYV rice in Bangladesh in comparison with other Asian countries.

1.3 The Objective of the Study

The rate of adoption of HYV rice is much slower than expected. The whole rice self-sufficiency program depends on how fast HYV rice is being adopted by the farmers. An attempt has been made in this study to identify the factors that are assumed to be important in the early stage of diffusion of HYV rice in Bangladesh and to examine the diffusion process. This information would seem very crucial for policy-making in respect of government planning for increased production through HYV.

The geographic territory which now comprises Bangladesh has been subjected to planning for economic development since the early 1950s, and it is assumed that the results of the present findings should be of interest to the planning authority with regard to their foodgrain self-sufficiency program. The most crucial point of the future agricultural development will be to meet the staple food requirement of a population increasing at a rate of 3 per cent per annum.

TABLE 1.3

PROPORTION OF TOTAL RICE AREA PLANTED TO HYV IN ASIAN COUNTRIES
(1965-1972)

Country	1956-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73
India	.02	2.5	4.9	7.3	11.5	14.9	19.6	23.5
Bangladesh	-	.002	0.7	1.6	2.6	4.7	6.7	11.1
Nepal	-	-	-	3.7	3.8	5.7	6.3	16.1
Pakistan	-	.01	0.3	19.8	32.0	36.6	50.0	43.5
Sri Lanka	-	-	-	1.2	4.9	4.8	5.0	34.0
Burma	-	-	0.1	3.5	3.1	4.0	3.9	4.4
Indonesia	-	-	-	2.5	10.2	11.0	16.8	18.0
Laos	-	.04	0.1	0.3	0.3	8.1	4.5	7.5
Malaysia	10.3	15.4	23.1	20.9	26.5	31.4	37.0	39.0
Philippines	-	2.7	21.2	40.6	43.5	50.3	56.3	54.0
Thailand	-	-	-	-	0.1	1.6	4.2	5.3
South Vietnam	-	-	0.2	1.7	8.3	20.0	25.7	30.9
Republic of Korea	.1	1.4	3.5	6.6	9.9	12.9	17.0	20.4

Source: D. Dalrymple (1974), Development and Spread of High Yielding Varieties of Wheat and Rice in Less Developed Nations.

1.4 Outline of the Study

This dissertation is divided into seven chapters.

Chapter 1 describes the problem and the objective of the study. Chapter 2 deals with the economic background of Bangladesh and the relationship between rice and the economy including rice culture practices in Bangladesh.

Chapter 3 describes the approach to the study of the diffusion process. Chapter 4 deals with the hypothesis and the derivation of the model which is estimated, and deals with the techniques of econometric estimation used and the problems encountered in estimation.

Chapter 5 presents the data in terms of the selected variables and data transformation and adjustment, and comments on the reliability of the data. Chapter 6 presents the results of estimation.

Chapter 7 presents the concluding remarks about the study's findings in relation to earlier research.

CHAPTER 2

RICE AND THE ECONOMY

2.1 The Economy

Bangladesh, as an economy, possibly faces one of the most difficult tasks of economic development at this point of time due to mounting population pressure and limited cultivable land. The size of the population is approximately 72 million according to the 1974 population census and the area of Bangladesh is 55,126 square miles. The average density of population is 1,375 persons per square mile - one of the highest population densities in the world. 91.22 per cent of the total population is rurally based and the average literacy rate for the country as a whole is 22.2 per cent. Bangladesh has one of the lowest average per capita incomes in the world at approximately $US100 per annum. Nearly 45 per cent of the total population is under 15 years of age, depicting a high degree of dependency burden. 76 per cent of the total labour force is engaged in the agricultural sector.

The average size of farms is 2.5 acres and there is extremely limited possibility of extension of cultivated land. A third of the cultivated land is subject to annual flooding, coupled with occasional cyclones and tidal waves along the coastal areas.

According to the FAO Production Year Book (1973), while the population index has risen to 141 (1961-65 = 100), food production has risen to 122 (1961-65 = 100). Possibly nowhere else in the world has such an extremely low level of living and the extreme poverty is shared by vast masses of population all over the country. Life in a material sense is extremely poor in the country. All the economic and demographic indices of Bangladesh indicate a very low subsistence level economy. Possibly the word "subsistence" is not enough to convey the real meaning of the situation in some areas at least at this point of time. This is an economy moving around the margin of disaster.

2.2 The Physical Features of the Country

Bangladesh is a vast low alluvial plain with marginal hilly areas in the north and the south east. The average elevation of this alluvial plain is about 30 feet above sea level. The plains are watered by one of the most remarkable networks of rivers in the world. The rivers and the streams are the most conspicuous feature of the landscape in Bangladesh. Every year these rivers and streams overreach their banks in the monsoon and deposit silts on the surrounding areas. In the process, a typical alluvial plain has been created with natural levees along the banks of the rivers, streams and swamps which make an ideal condition for rice cultivation. The southern part of the country is deltaic and all the rivers in the deltaic region are continuously experiencing shifts in their main channels and this makes control of the water system very difficult.

The monsoon months (June to September) comprise the wet season and this period plays the most dominant role in the agrarian economy in general and rice cultivation in particular.

The mean minimum temperature varies from 49.6°F to 56.2°F in January and mean maximum temperature varies from 77.9°F to 78.9°F in July.

The annual rainfall varies from 50 inches in the west to 100 inches in the south east and to 200 inches in the sub-Montane region of Assam Hills in the north. Nearly 80 per cent of rain falls between June to October during the monsoon. Winter rainfall in most years is negligible.

2.3 The Agrarian Economy

Agriculture contributes approximately 60 per cent to the GDP of Bangladesh. Every available acre of land is very intensively cultivated to grow agricultural commodities, mainly food crops. Most of the farmers are basically subsistence farmers. An average land-owning farmer has only 1.5 acres, rents another acre from a well-to-do farmer and therefore cultivates 2.5 acres. The government has placed a ceiling of 33 acres of land ownership for each farmer in 1972, but in fact only 0.5 per cent of the farms are larger than 25 acres. About 77 per cent of the farms in Bangladesh are under 5 acres and 24 per cent of them are smaller than one acre. About 40 per cent of the pesants are landless.

The problem of having small farms is further complicated by the fact that a single farm is rarely in a single compact unit. It is usually scattered in small plots in distant places surrounding the farmer's village causing enormous labour wastage in the time spent moving from one plot to another. The stupendous scale of subdivision and fragmentation of landholdings is the result of hereditary laws in an economy where population has increased without any corresponding increase in the supply of cultivable land. The extent of subdivision and fragmentation can be assessed from Table 2.1.

The fragmentation of farms has necessitated many demarcation lines to identify holdings. These demarcation lines have always been made by slightly raised earthen embankments and it is estimated that an area of about 250,000 acres of land are taken up with these demarcation lines, thus rendering this area useless.

The farming techniques in Bangladesh are still mostly traditional. Mechanisation on a large scale has yet to arrive. The tools and implements of the farmers are few and simple. Most common tools are the metal pointed wooden plough to till the land; split bamboo ladders to level off the land; short-handled hoe shovel, hand scythe, heavy bladed knife and a pair of bullocks. Needless to say, an enormous amount of back-breaking human labour is required at every stage from sowing to harvesting. More than one crop is usually raised in a year from the land.

TABLE 2.1

SUBDIVISION AND FRAGMENTATION OF LANDHOLDINGS IN BANGLADESH

Type	No. of farms (million)	Percentage of all farms
All farms	6.14	100
Farms not fragments	0.62	10
Farms with 2 or 3 fragments	1.29	21
Farms with 4 or 5 fragments	1.08	17
Farms with 6 or 9 fragments	1.39	23
Farms with 10 or more fragments	1.76	29

Source: H.E. Raschid (1965), East Pakistan: A Systematic Regional Geography and Development Aspects, p.122.

In the year 1969-70, 55.3 per cent of the cropped area was single-cropped, 34.8 per cent was double-cropped and 6.2 per cent was triple-cropped. The degree of intensity of cropping can be observed from Table 2.2.

2.4 The Role of Rice in the Economy

Among the crops grown, rice looms large in the economic and social life of Bangladesh. Its culture is so widespread and its use as a food is so popular that rice is cultivated all over Bangladesh and consequently is the staple food in the diet of the people of Bangladesh. The production of rice plays such an important role in the economy of Bangladesh that it is understandable the way people attach so much importance to rice cultivation. 77.6 per cent of the total cultivable area was under rice during the year 1969-70 and the trend is increasing.

TABLE 2.2

LAND UTILISATION IN BANGLADESH, 1969-70

Name of district	Intensity of cropping (percentage)
Dacca	154
Mymensing	172
Tangail	188
Faridpur	173
Chittagong	135
Chittagong Hill Tracts	184
Noakhali	148
Comilla	162
Sylhet	133
Rajshahi	132
Dinajpur	140
Rangpur	175
Bogra	159
Khulna	130
Banisal	151
Patuakhali	123
Jessore	137
Kushtia	132
Bangladesh	150

Source: G.O.B. (1973), Bangladesh Agriculture in Statistics, p.43.

Rice contributed 28 per cent to the GDP in the early seventies. A United States AID mission at Dacca in 1968 found that there was a correlation of almost .99 between the volume of rice production and the GDP. Bangladesh accounts for 7.1 per cent of the total area under rice and occupies third position among the rice growing countries. The rice industry is the largest employer of civilian labour in the country.

Out of the total average consumption of 2073 calories per head, per day, 1662 calories come from grains (i.e., mostly rice). See Table 2.3.

TABLE 2.3

FOOD BALANCE SHEET OF BANGLADESH, 1962

Food groups	Calories (head/day)
Grains	1,662
Pulses	56
Roots, tubers and starches	18
Oils and fats	38
Fruits and vegetables	94
Meat	13
Fish	37
Milk	35
Eggs	1
Sugar	119
TOTAL:	2,073

Source: H.E. Raschid (1965), East Pakistan: A Systematic Regional Geography and Development Aspects, p.368.

2.5 Rice Culture in Bangladesh

Because of the factors discussed earlier, there is no indication that any other crop can replace rice at present and rice is and will be grown by the farmers on their farms for several reasons:

1. Rice is the most preferred food and the level of per capita income also does not suggest that people can switch over to costlier foods like meat and vegetables in larger quantities to substitute for cereals.
2. The geographic position and the climatic conditions make Bangladesh suitable for rice cultivation.
3. The price of rice in the recent past shows a rising trend which makes rice production more profitable.
4. Farmers have a built-in technical skill in rice production and the rice technology is more advanced than that of other crops.

Bangladesh rice production technology has been dominated by the varieties planted with limited capacity to utilise fertiliser effectively. The introduction of modern mechanical techniques are limited by the size of the farm and the scale of operation. Traditional varieties of rice in Bangladesh are relatively tall with weak-stemmed stalks. Farmers have been only able to use a very limited quantity of fertiliser because if additional units of fertiliser are applied, heavier heads cause the plants to fall down or lodge, thus limiting the potential increase in yield. These conditions have presumably caused rice cultivation technology to remain largely unchanged for centuries. Increased output of rice will be heavily dependent upon major changes in rice cultivation technology through water control systems, fertiliser and increased plant population densities.

Bangladesh has one of the lowest rice yields in the world. The following table indicates the low yield of rice in Bangladesh in comparison with other Asian rice producing countries:

TABLE 2.4

RICE PRODUCTION IN ASIA

Country	1971	1972 (kg/hectare)	1973
Japan	5,243	5,848	6,018
Republic of Korea	4,631	4,618	4,794
China	3,137	3,088	3,209
Indonesia	2,270	2,259	2,373
Sri Lanka	2,366	2,054	1,956
World	2,293	2,252	2,390
Asia	2,305	2,253	2,409
Bangladesh	1,602	1,572	1,837

Source: FAO Production Year Book, 1973, p.46-47.

The following table gives a description of total area under rice, total production of rice and yield per acre:

TABLE 2.5

ACREAGE, PRODUCTION AND YIELD OF RICE IN BANGLADESH

Year	Area (in acres)	Production (in tons)	Yield (in maunds)
1970-71	24.05 ml	10.80 ml	12.34
1971-72	22.97 ml	9.77 ml	11.97
1972-73	23.79 ml	9.93 ml	12.06
1973-74	23.70	11.72	18.07
1974-75	23.92	11.32	15.34

Source: G.O.B. (1975), Economic Survey of Bangladesh, 1974-75, p.8.
1 maund - 37 kg.

Rice production in Bangladesh is undertaken in favourably endowed geographic conditions in the world's largest rice producing and consuming area. Geographic and weather conditions not only make Bangladesh suitable for rice cultivation but also determine the cropping pattern of rice. Three separate cropping seasons and four different rice varieties with each rice variety adapted to particular seasonal and hydrological conditions and farming techniques have evolved over many years.

In spite of the large degree of uniformity in rice cultivation practices, there is a certain degree of variation in the regional pattern of rice cultivation. Each variety of rice consists of many types, most of which are based on quality and type of grain whether it is fine, long, small, medium or bold.

The three agricultural seasons are mutually overlapping and are named after the period when the crops are harvested. The three agricultural seasons are: (i) Bhadoi season when the Aus variety of rice is harvested; (ii) Haimantik season when both varieties of Aman are harvested; (iii) Rabi season when the Boro variety of rice is harvested.

In the year 1972-73, out of a total of 23.6 m acres under rice, 7.2 m acres were under Aus, 4.6 m acres were under Broadcast Aman, 9.4 m acres were under Transplanted Aman and 2.4 m acres were under Boro. In the same year, from yield data on a per acre basis, Boro had the highest yield followed by Transplanted Aman, Aus and Broadcast Aman.

2.6 The New Rice Technology

In the light of the chronic food grain shortage and mounting population pressure, it seemed that it was impossible to rely on traditional varieties of rice to attain food grain self-sufficiency. The traditional varieties of rice do not respond well to fertiliser applications. Moreover, there is little or no possibility of increasing the acreage under rice without increasing the intensity of cropping. The way taken out from this impasse was to look for new or improved rice varieties suitable to climatic and cultural practices in the country. There is no denying the fact that it was the need for more foodgrains which originally inspired the search for new and better methods of rice production. The policy-makers have decided to use the new technology as the major means to pursue the objective of increased rice production.

The new rice technology as it is being used in the country has been pioneered by the International Rice Research Institute (IRRI) at Los Banos in the Philippines. A number of varieties of new rice seeds with dramatic high yielding potential have been produced by IRRI. The performance of these HYV rice seeds is environment specific and higher yields can only be obtained from these seeds under appropriate circumstances.

The first HYV rice IR8 was released in late 1966 by IRRI and this was followed by IR5 in 1967 and then by IR20 and IR22 in 1969 and IR24 in 1971. All new rice varieties were available in Bangladesh soon after they were released by IRRI.

Although HYV rice opened up enormous increased production possibilities, they require difficult adjustment in institutional and cultural practices to reap their potential benefits. Apart from IRRI, the Bangladesh Rice Research Institute at Dacca has also contributed towards developing new HYV rice in Bangladesh. The most successful HYV rice varieties to be introduced to date in Bangladesh under the research program of IRRI and BRRI are given below:

IR8: This strain was available in Bangladesh immediately after it was released from IRRI for use in 1966. At the beginning it was tried for all three seasons of rice cropping but the variety showed very little adaptibility to Aus or Aman seasons. It showed a greater degree of adaptibility during the Boro season, although it requires more irrigation water and a longer growing period than traditional varieties grown in the Boro season. IR8 has much higher yields than traditional varieties and with higher doses of fertiliser and pest control its yield can increase substantially. This HYV rice is susceptible to tungro virus, bacterial leaf blight and cold weather.

IR5: Its plants are taller than IR8 and it is drought resistant. This variety is generally grown during Aman season. This variety is very thermosensitive and is susceptible to diseases.

IR20: This is a short straw variety and adaptive to the monsoon season. This HYV rice has certain improved qualities such as better grain quality, resistance to insects and to certain diseases. Because of these qualities it has the widest adaptibility in the transplanted Aman season.

CHANDINA: This is a short straw variety and more cold tolerant than IR8 and its grain quality is also better. It is more pest and disease resistant. It is primarily an IR8 local replacement. Although it was designed for Boro and Transplanted Aus, it has shown excellent results for late Transplanted Aman in many places of the country.

MALA: This HYV rice is recommended for rainfed Broadcast Aus but generally it is grown as Boro and Transplanted Aus. It has the highest number of spikelets per panicle among the HYV rices but its sterility percentage is also higher.

PURBACHI: This HYV rice is used for Boro cultivation but is very susceptible to diseases and is grown where early harvest is needed.

BR3: It is a better replacement for IR8 in the sense that it is resistant to bacterial leaf blight and has some resistance to tungro virus but its grain quality, plant type and growth period are the same as IR8.

BRRI SAIL: This variety was developed from the cross IR20 x IR5 and is recommended for Transplanted Aman season. It is the latest in the series by BRRI. This variety is an improvement over both IR20 and IR5 in certain respects.

To reap the full benefits from these HYV seeds, the complete range of supplementary inputs are also required to be made available to the farmers like fertiliser, pesticide, fungicide, herbicide, irrigation, proper land preparation, correct timing in transplanting, and the correct plant population per acre.

In the light of the current prevalent traditional agricultural practices these are radical changes and have definitely put the research organisations and the extension services under heavy pressure. It is evident that though the new rice technology has opened up enormous production possibilities, the increased yield can only be obtained by use of increased inputs.

2.7 Seasonal Distribution of HYV Rice

The new rice technology over the last few years seems to be in the process of making new adjustment to different rice growing seasons. In 1969-70 HYV Boro contributed 88.93 per cent to total HYV rice production but the contribution of HYV Boro went down to 41.36 per cent in 1972-73 - four years later. During the same period the contribution of HYV Aman to total HYV rice production rose from 4.48 per cent to 52.41 per cent. In percentage figures more acres are under HYV rice in the Boro season than during the Aman season. This indicates that although HYV rice was originally found suitable for the Boro season it is becoming more adaptable to Aman and Aus seasons with the breeding of new HYV rice varieties suitable to Aman and Aus seasons. There is a gradual increase in acreage under HYV Boro and HYV Aman but the rate of increase was higher for HYV Aman than for HYV Boro during the period under study. The rate of increase in acreage under HYV rice in different seasons can be observed from Table 2.6.

Across the country it appears that HYV acreage compared to total acreage under rice differs significantly from district to district. Table 2.7 indicates that Chittagong, Chittagong Hill Tracts and Comilla have the highest proportion of acreage under HYV rice compared with total acreage under rice in those districts. Conversely, Faridpur, Pabna and Rajshahi have the lowest percentage of acreage under HYV rice during the same period.

The seasonal distribution of acreage under HYV rice also shows different degrees of adjustment between the seasons in different districts. In 1972-73, out of 19 districts, 10 districts had more acreage under HYV Boro than under HYV Aman while the remaining 9 districts had more acreage under HYV Aman than under HYV Boro. Table 2.8 indicates the seasonal distribution of acreage under HYV rice in different districts.

The Boro season needs some special attention here because when HYV rice was first released in the latter half of the 1960s, it was found suitable for only the Boro season. This season is the dry season in Bangladesh which meant that HYV rice grown in the Boro season could be produced only with the help of irrigation water. Table 2.9 indicates that in terms of absolute acreage Mymensingh, Chittagong, Dacca, Sylhet and Comilla have more acreage under HYV Boro than in other districts, and from figures shown in Table 2.10 it will be noted that the acreage under mechanised irrigation is also higher in those districts.

Extension of acreage under HYV Boro is only possible by extending the acreage under mechanised irrigation. Mechanised irrigation is capital intensive which Bangladesh can ill afford on a large scale with the present state of economic conditions in that country. It was therefore necessary to develop HYV rice varieties suitable for rainfed areas where rainfall is assured and which are generally free from flood damage.

TABLE 2.6

ACREAGE UNDER HYV RICE IN DIFFERENT SEASONS IN BANGLADESH
(in '000 acres)

	1969-70			1970-71			1971-72			1972-73		
Seasons	HYV	Total	% HYV	HYV	Total	% HYV	HYV	Total	% HYV	HYV	Total	% HYV
Aus	42.9	8,461.9	0.51	79.9	7,884.8	1.01	120.6	7,417.8	1.62	163.7	7,240.7	2.26
Aman	29.2	14,841.2	0.20	199.8	14,184.3	1.41	625.6	13,371.6	4.68	1,378.6	14,120.0	9.76
Boro	579.5	2,183.1	26.54	857.2	2,425.5	35.34	795.4	3,185.3	24.97	1,088.0	2,434.1	44.70
Total	651.6	25,486.2	2.56	1,136.9	24,494.6	4.64	1,541.6	23,974.7	1.43	2,630.3	23,794.8	11.05

Source: G.O.B. (1973), Bangladesh Agriculture in Statistics.

TABLE 2.7

ACREAGE UNDER HYV RICE IN DIFFERENT DISTRICTS, BANGLADESH
(in '000 acres)

	1969-70		1970-71		1971-72		1972-73	
Districts	HYV	Total	HYV	Total	HYV	Total	HYV	Total
Dacca	72.7	1,442.8	85.0	1,254.8	136.0	1,275.0	187.4	1,305.1
Mymensingh	117.5	3,905.4	159.4	3,106.0	250.6	3,120.4	447.9	3,198.3
Tangail	-	-	22.9	492.5	28.0	602.9	49.3	714.2
Faridpur	12.3	1,394.9	28.1	1,211.8	27.1	1,072.2	38.4	1,339.1
Chittagong	83.7	905.8	151.7	902.4	195.6	900.9	281.7	966.7
Chittagong Hill Tracts	13.8	217.5	13.8	205.6	26.6	197.7	29.2	155.6
Noakhali	36.2	1,249.9	54.0	1,153.5	87.4	1,276.9	130.5	1,218.0
Comilla	92.0	1,711.4	125.9	1,716.8	146.8	1,616.4	236.1	1,616.0
Sylhet	58.5	2,240.6	81.1	2,266.0	90.5	1,983.4	224.2	1,916.1
Ratshahi	17.0	1,675.5	25.2	1,701.0	40.4	1,456.0	80.0	1,648.5
Dinajpur	17.0	1,380.4	50.1	1,391.6	27.1	936.8	130.6	1,027.5
Rangpur	19.1	2,148.7	44.5	2,238.6	129.0	2,241.3	187.2	2,163.6
Bogra	8.9	950.4	35.7	923.4	57.4	839.2	115.6	915.9
Pabna	8.8	1,003.4	13.0	844.6	19.3	833.5	36.3	805.3
Khulna	12.4	1,168.9	27.9	1,064.7	38.9	902.2	75.0	901.8
Barisal	65.6	2,271.5	113.4	1,465.6	131.1	1,375.9	206.9	1,487.6
Patuakhali	-	-	55.7	871.9	66.0	745.2	88.4	810.0
Jessore	17.6	1,208.1	32.4	1,176.9	31.6	1,216.5	56.5	1,118.0
Kushtia	2.5	511.0	17.1	491.9	12.2	382.3	29.1	427.5

Source: G.O.B. (1973), Bangaldesh Agriculture in Statistics.

TABLE 2.8

SEASONAL DISTRIBUTION IN ACREAGE UNDER HYV RICE IN BANGLADESH
(in '000 acres)

	1969-70			1970-71			1971-72			1972-73		
District	Aus	Aman	Boro	Aus	Aman	Boro	Aus	Aman	Boro	Aus	Aman	Boro
Dacca	2.0	1.0	69.7	1.8	12.6	70.6	10.2	35.5	90.3	14.1	51.3	122.0
Mymensingh	9.4	2.9	86.9	9.6	23.8	126.0	23.1	108.6	118.9	30.6	252.9	164.4
Tangail	-	-	18.4	0.5	2.1	20.3	0.7	9.5	17.8	0.8	18.3	30.2
Faridpur	-	-	12.3	-	0.1	28.0	-	0.1	27.0	0.1	0.4	37.9
Chittagong	2.1	2.4	79.2	4.1	27.9	119.8	12.5	60.5	122.6	10.4	128.5	142.8
Chittagong Hill Tracts	2.7	0.6	10.5	3.4	0.7	9.7	3.8	11.7	11.1	6.2	10.5	12.5
Norkhali	1.6	3.7	30.9	5.5	7.6	40.9	7.8	21.5	58.1	19.3	51.3	59.9
Comilla	5.2	2.1	84.7	12.3	8.9	104.7	8.5	47.8	90.5	23.3	113.0	99.8
Sylhet	3.5	0.5	54.5	9.6	11.5	60.0	11.4	23.5	55.6	5.2	108.0	111.0
Rajshahi	0.7	1.0	15.3	0.7	1.7	22.8	0.6	12.5	27.3	0.5	38.0	41.5
Dinajpur	5.9	2.8	4.3	5.6	33.1	11.4	4.5	20.0	2.6	7.1	114.0	9.5
Rangpur	1.7	2.4	15.0	1.3	23.7	19.5	3.3	110.3	15.4	2.1	160.8	24.3
Bogra	0.6	0.7	7.6	0.3	19.2	16.2	0.4	45.0	12.0	0.6	93.2	21.8
Pabha	0.2	-	8.6	0.1	0.1	12.8	0.1	4.8	14.4	0.2	12.0	24.1
Khulna	-	3.8	8.6	5.2	2.5	20.2	13.4	12.2	13.3	6.1	49.5	19.4
Barisal	4.4	3.3	42.6	1.4	8.3	103.6	3.6	56.7	70.8	5.9	105.1	95.9
Patuakhali	-	-	15.3	5.3	0.4	50.0	3.8	25.9	36.3	5.0	28.3	55.1
Jessore	1.8	2.0	13.1	5.6	9.3	17.5	4.9	16.8	9.9	14.5	28.8	13.2
Kushtia	1.1	-	1.4	7.6	6.4	3.1	8.0	92.7	1.5	11.7	14.7	2.7

Source: G.O.B. (1973), Bangladesh Agriculture in Statistics.

TABLE 2.9

ACREAGE UNDER HYV BORO
(in '000 acres)

District	1969-70 HYV	1969-70 Total	1970-71 HYV	1970-71 Total	1971-72 HYV	1971-72 Total	1972-73 HYV	1972-73 Total
Dacca	69.7	178.4	70.6	179.6	90.3	186.3	122.0	206.7
Mymensingh	86.8	557.4	126.0	584.0	118.9	555.3	164.4	601.8
Tangail	18.4	49.8	20.3	51.5	17.8	41.1	30.2	54.0
Faridpur	12.3	31.7	28.0	46.3	27.0	43.8	37.9	57.3
Chittagong	79.2	143.4	119.8	167.4	122.6	157.2	142.8	151.5
Chittagong Hill Tracts	10.5	31.5	9.7	29.2	11.1	21.4	12.5	19.7
Noakhali	30.9	44.7	40.9	52.2	58.1	68.3	59.9	70.0
Comilla	84.7	168.8	104.7	187.5	90.5	167.4	99.8	174.7
Sylhet	54.5	656.3	60.0	669.4	55.6	578.6	111.0	628.8
Rajshahi	15.3	90.4	22.8	95.0	27.3	84.2	41.5	97.4
Dinajpur	4.3	7.0	11.4	13.4	2.6	3.7	9.5	11.5
Rangpur	15.0	32.5	19.5	35.0	15.4	30.0	24.3	37.2
Bogra	7.6	30.3	16.2	36.6	12.0	30.0	21.8	38.9
Pabna	8.6	21.1	12.8	26.5	14.4	29.4	24.1	42.4
Khulna	8.6	41.9	20.2	53.7	13.3	47.7	19.4	41.8
Barisal	42.6	56.2	103.7	116.1	70.8	84.3	95.9	109.7
Patuakhali	15.3	18.9	50.0	53.5	36.3	38.1	55.1	65.4
Jessore	13.8	19.9	17.5	23.7	9.9	14.9	13.2	19.3
Kushtia	1.4	2.9	3.1	4.9	1.5	3.6	2.7	5.0

Source: G.O.B. (1973), Bangladesh Agriculture in Statistics.

TABLE 2.10

MECHANISED IRRIGATION IN BANGLADESH
(in acres)

District	1970-71	1971-72	1972-73	1973-74	1974-75
Dacca	590	425	2,235	4,580	151,008
Mymensingh	4,415	3,605	3,195	13,320	215,296
Tangail	34,518	29,691	32,020	41,553	57,891
Faridpur	118	594	3,619	535	52,158
Chittagong	89,631	95,607	12,114	108,105	124,867
Chittagong Hill Tracts	7,654	8,919	10,001	7,994	8,000
Noakhali	29,339	26,195	30,595	43,707	35,280
Comilla	77,788	100,216	136,728	136,102	174,653
Sylhet	88,610	84,602	149,995	146,241	142,348
Rajshahi	44,664	40,963	89,757	68,623	60,437
Dinajpur	4,622	6,519	12,703	16,847	19,966
Rangpur	18,166	21,227	24,307	34,470	31,522
Bogra	19,554	17,802	24,359	27,204	46,513
Pabna	20,970	20,702	24,472	30,753	36,098
Khulna	13,687	20,281	38,097	47,065	28,240
Barisal	99,891	86,659	150,805	158,935	71,216
Patuakhali	49,009	40,098	57,044	65,532	113,617
Jessore	14,908	16,583	40,935	25,268	19,073
Kushtia	3,736	5,190	8,456	11,878	13,762

Source: Bangladesh Agricultural Development Corporation.

This has led to the development of several HYV rice varieties suitable for Aman and Aus seasons. At the moment it appears that HYV Aman acreage is increasing at a greater rate than HYV Boro. By introducing HYV Aman, farmers are saving costs to the extent that irrigation water is not required. This cost consideration, coupled with the possibility of double cropping of rainfed HYV Aus followed by HYV Aman, will possibly mean a continuous increase in the acreage under both HYV Aus and HYV Aman in the future.

According to the latest survey, 6.3 million acres of land in the country are potentially available for rainfed HYV Aus production, 6.6 million acres for rainfed HYV Aman production and 3.0 million acres for double cropping of HYV Aus followed by HYV Aman.

2.8 The Impact of New Rice Technology

The introduction of new technology in agriculture is primarily considered from the point of view of increased production, but the ultimate goal of new technology development in the less developed countries of the world is the improvement of the welfare of the people in the rural and urban areas. Rice production is one of the most important elements that determines the welfare of the rice producing societies. It is therefore of the utmost importance to look into the likely consequences of the introduction of new technology on the general welfare of the people in Bangladesh.

Terms such as "green revolution" or "seed-fertiliser revolution" have been used to describe the introduction of new rice technology to Bangladesh and in Asia. The validity of such assertions is much in doubt despite the fact that rice yields have increased in recent years with the introduction of new rice technology. It is certainly true that there has not been any revolutionary change, rather an evolution in the aggregate sense and this evolution has been marked by rapid change in certain areas with no change in other areas.

An international seminar on the socio-economic implications of introducing HYV rice in Bangladesh was held at the Bangladesh Academy for Rural Development at Comilla in April 1975. While acknowledging the potentialities of the "miracle seed", grave concern was expressed because of the fact that it did not come up to the expectations of the society. The reasons advanced for such concern was that it was accentuating rural income inequality in an impoverished rural economy. It was also pointed out that increased profit margins from HYV rice might lead to labour substituting technology in an economy where laarge numbers of landless peasants depend on rural employment. The heavy dependence of HYVs on fertiliser and pesticides (TK. 3600m 1973) imposed a heavy burden on the economy, especially in terms of demand for foreign currency.

The suggestions for removing the problems were that the government should start a long-term strategy of solving income inequality in the rural areas, but for the immediate future it was necessary to implement politically feasible policies to minimise social inequality while pursuing the goal of increased foodgrain production.

CHAPTER 3

REVIEW OF LITERATURE

3.1 Technological Change

Technological change in production is the principal factor of structural change and resource use adjustment in economic development. Technological change implies a change in existing knowledge of means of production. It may also imply either the use of a new input or an improved version of the traditional inputs, leading to increased productivity of resources used in production.

Technological change is always viewed from the point of view of a production function. A production function is usually presented in mathematical form, indicating the relationship between inputs and output. All the technically feasible combinations of the inputs set the limits for the production functions. Therefore, technological change may be described as either modification of the existing production functions or creation of new production functions.

Technical change usually conveys the idea of increasing production, but it may also mean the reduction of losses through better storage and harvesting systems. Whatever form it takes technological change usually leads to different factor combinations.

3.2 Technological Change in Agriculture

Heady (1949) has suggested that technological change in agriculture can be divided into (i) biological, (ii) mechanical, and (iii) biological-mechanical. By biological he refers to those changes which have a physiological effect in increasing the total output from a given land base. By mechanical he refers to a mechanical innovation which substitutes capital for labour, but does not change the physiological outcome of the plants or animals to which it may apply. Many mechanical innovations also have a physiological effect in increasing timeliness of operations, soil structure or otherwise directly affecting the plants or animals. The techniques which have both these effects are termed biological-mechanical.

3.3 Diffusion of New Technology

Technological change is probably the most crucial factor in determining the shape of an economy. Technological change has enhanced the flow of products, adding new dimensions to the way of life, and improving working conditions. Interest in the study of the economic aspects of new technology stems from the study of the process of economic growth. Huge amounts of money are being spent by research organisations in creating new technology, but the benefits of this huge amount of research remain unrealised until the resulting new technology is diffused. Most new technologies are not widely adopted for a considerable number of years, so the rate of diffusion or adoption of new technology is of great importance. One implicit or explicit purpose behind the study of diffusion is to determine methods by which the rate of diffusion can be accelerated.

3.4 Approaches to the Study of Diffusion

By the late sixties, the new rice technology started to make its impact felt in Bangladesh with the introduction of HYV rice. Previously rice production technology had been limited to the traditional varieties, with its concomitant centuries old production method. Before looking into the diffusion of HYV rice in Bangladesh it will be proper to look into some of the studies that have already been published in the field of diffusion of new technology. This will provide better analytical insight into the economic aspects of the diffusion process and will help in modelling the diffusion of HYV rice in Bangladesh.

Griliches (1957) studied the factors responsible for wide cross-sectional differences in the rates of adoption of hybrid corn in the United States.

In the course of his study he argued that Graphic Surveys of data on diffusion for each State or crop reporting district were of little value for economic analysis. The observations were not points of equilibrium which may or may not change over time, but points on an adjustment path, moving more or less consistently towards a new equilibrium which may or may not change over time, but points on an adjustment path, moving more or less consistently towards a new equilibrium position. So it should be analysed in terms of the beginning of the movement, its rate, and its destination. This led him to fit some simple trend functions to the data and to concentrate on the explanation of the cross-sectional difference in the estimation of parameters.

His choice of a particular algebraic form for the trend function was somewhat arbitrary. As the data was markedly S-shaped, several simple S-shaped curves were considered. The cumulative normal and logistic curves are used widely for such purposes. As there are almost no differences between the two over the usual range of data, the logistic was chosen because it was more easily calculated and interpreted. While there are some good reasons why an adjustment process should follow a path which is akin to a logistic function he does not want to argue the relative merits of the various S-shaped curves. He pointed out that the growth curve served as a summary device, perhaps somewhat more sophisticated than a simple average, but which should be treated in the same spirit.

The logistic growth curve is defined as:

$$P = K/[1 + e - (a + bt)]$$

where P is the percentage planted with hybrid seed, K is the ceiling or equilibrium value, t the time variable to the rate of growth coefficient and a is the constant of integration which positions the curve on the time scale. Several features of the curve are of interest. It is asymptotic to zero and K, symmetric around the inflection point, and the first derivative with respect to time is given by $dP/dt = -b\ (P/K)\ (K-P)$. The rate of growth is proportional to the growth already achieved and to the distance from the ceiling. It is this last property that makes the logistic curve useful in so many diverse fields.

There are several methods of estimating the parameters of the logistic curve. The method chosen involved the transformation of the logistic into an equation linear in a and b. By dividing both sides of the logistic by (K-P) and taking the logarithm, a linear transformation can be obtained.

$$\log_e\ [P/(K-P)] = a + bt$$

Using the least squares regression method the parameters were estimated. The value of K, the ceiling, was estimated crudely by plotting the percentage planted to hybrid seed on logistic graph paper and varying K until the resulting graph approximated a straight line. After adjusting for differences in K, the logistic curve was fitted to the data covering approximately the transition from 5 per cent to 95 per cent of the ceiling. The observations below 5 per cent and above 95 per cent of the ceiling value were discarded because they were liable to very large percentage errors. The period included here in the analysis, however, accounts for the bulk of the changes in the data.

The procedure outlined above was used to calculate the parameters of the logistic curve for 31 States and for 132 crop reporting districts within these States.

Differences in the slope or adjustment coefficient (b) may be interpreted as differences in the rate of adjustment of demand to new equilibria, and will be explained by variables operating on the supply side. b indicates by how much the value of the logistic transformation will change per unit of time. The path traced out is an intersection of short run supply and demand durves. It was assumed that while shifts on the supply side determine the origin of development, the rate of development is largely a demand or acceptance variable. The usefulness of this variable is due to a very elastic long run supply of seed.

Differences in the rate of adoption of hybrid corn were due, at least in part, to the differences in the profitability of changeover from open pollinated to hybrid seeds. This hypothesis was based on the general idea that the longer the stimulus the faster is the rate of adjustment to it. Also, in a world of imperfect knowledge it takes time to realise that things have changed. The larger the shift the faster will entrepreneurs become aware of it, and hence they will react more quickly to larger shifts.

The author hypothesised that the rate of adoption of new technology is a function of the profitability of the shift from open pollinated to hybrid seeds, both per acre and total. Per acre profitability was defined as the increase in yield due to the use of hybrid seeds times price of corn minus the differences in the cost of new seeds.

The model he formulated was used to calculate the parameters of the logistic curve for 31 States and 132 crop reporting districts within these States. The States used accounted for almost all the corn grown in the USA (except West and New England). Several noteworthy facts about the results obtained were the excellent fit obtained as indicated by the high R^2; the values of b's, i.e., the rate of adoption, gave appropriate results indicating lower rates of adoption towards the fringes of the corn belt. The value of $[-2.2 - a/b]$, the dates of origin, indicate that the development started in the heart of the corn belt and spread towards its fringes. The ceiling K also declined as it moved away from the corn belt. The results were in line with the theoretical expectations of the author.

It should be noted that Griliches concentrated on the long run aspects of technological change, interpreting differences in the pattern of development of hybrid corn on the basis of the long run characteristics of various areas, and ignored short run fluctuations in prices and incomes.

Rogers (1962) studied diffusion of innovation from a sociological point of view. He listed five stages in the process of adoption of a new technology: (i) awareness, (ii) interest, (iii) evaluation, (iv) trial, and (v) adoption.

At the awareness stage the individual is exposed to the innovation but lacks complete information about it. At the interest stage the individual becomes interested in the new technology and seeks additional information about it. In the evaluation stage, the individual mentally applies the innovation to his present and anticipated future situation, and then decides whether or not to try it. At the trial stage the individual uses the innovation on a small scale in order to determine its utility in his situation. The main function of the trial stage is to demonstrate the new idea in the individual's own situation and determine its usefulness for possible complete adoption. At the adoption stage the individual decides to continue the full use of the innovation.

He also pointed out five factors that are important in affecting the rate of adoption of an innovation:

1. Relative advantage - is the degree to which an innovation is superior to the ideas it supercedes.
2. Compatibility - is the degree to which an innovation is consistent with existing values and past experiences of the adoptions.

3. Complexity - is the degree to which an innovation is relatively difficult to understand and use.

4. Divisibility - is the degree to which an innovation may be tried on a limited basis.

5. Communicability - is the degree to which the results of an innovation may be diffused.

It is clear that many of the factors which Rogers considers to be important sociological factors affecting diffusion are essential economic characteristics of the new technology which affect its adoption. It is not clear to what extent there are important sociological factors which cannot be handled within an economic framework.

Polasek and Powell (1964) carried out a study to see how synthetics were replacing wool in the leading wool consuming countries. They also prepared the Standard Statistical method for analysing the adoption of a new product which consists of fitting a mathematical trend function, such as the Gompertz Curve or logistic curve. For their analytical purposes they used the logistic function:

$$Y_t = K/[1 + e - (a + bt)]$$

where Y_t = synthetic's share of the market

K = the value of the upper limit approached by the series of Y_t over time

b = speed of approach towards the asymptote

a = a coefficient locating the logistic on the time scale.

The parameters K and b can be referred to as the ceiling and the rate of adoption respectively. The logistic constraint on the ceiling is taken as unity.

For the purpose of fitting the data, a linear transformation of the logistic is obtained:

$$Y_t = \ln[Y_t/(K - Y_t)] = a + bt$$

The estimation procedure consisted of computing the least squares regression of Y_t on time for a large number of values of K (successive values of K being separated by arbitrary small intervals), and selecting that value of K which yielded the minimum residual sum of squares. Where this method was not successful, other statistical criteria had to be used.

The statistical technique discussed beforehand will reduce the large body of data into three sets of coefficients. Of these, the origin-fixing parameter, a, possesses little practical meaning. Instead it would be more useful to try to pin down the effective starting data of the innovational process. As the logistic has no "beginning" being asymptotic to zero, the definition of origin of technological change is somewhat arbitrary in the model. As a measure, the point at which each national market began to adjust rapidly to synthetics, i.e., the date at which the computed market share Y_t reached 10 per cent of its ultimate ceiling value, has been considered to be the take-off date. The value of t at which this occurs is (-2.2 - a/b).

The results obtained show that the process of adaptation to synthetics has been far from uniform in the countries under review. The authors have been able to offer only partial explanations for this lack of uniformity. The authors pointed out that the results, while not necessarily reflecting the speed of diffusion of technological change, at least indicate the response in various countries to innovational change in a Schumpeterian market sense.

Mansfield (1968) constructed a model to see what factors determine the rate of initiation of an innovation. His model was concerned with innovations in the industrial sector.

Mansfield put forward several hypotheses. Firstly, the number of firms having introduced an innovation, if plotted against time, should approximate a logistic function. Secondly, the rate of imitation in a particular industry should be higher for more profitable innovations and for innovations requiring relatively small investment. More precisely, ϕij, a measure of the rate of initiation (diffusion), should be linearly related to πij (profitability of installing this innovation relative to that of alternative investment) and Sij (the investment required to install this innovation as a percentage of the average total assets of the firms).

To carry out the first step the original equation:

$$mij(t) = nij\ [1 + e - (lij + \phi ijt)] - 1 \qquad \ldots\ldots (1)$$

is transformed to be linear in logarithms and now the equation is:

$$\ln\left[\frac{mij(t)}{nij - mij}\right] = lij + \phi ijt \qquad \ldots\ldots (2)$$

Where mij(t) is the number of firms having introduced this innovation at time t; nij is the total number of firms in the i^{th} industry with j^{th} innovation.

Measuring time in years, treating this as a regression equation, and using least squares (after properly weighting the observations), estimates of lij and ϕij can be obtained.

The author used his model to look into 12 innovations in four different industries. Results so obtained were consistent with the model. The coefficients of ϕij and Sij have the expected signs (indicating that an increase ϕij and a decrease in Sij increase the rate of initiation) and both differ significantly from zero.

The author conceded that there were problems associated with the available data which may bias the coefficients towards zero. He measured the rate at which firms initiated an innovation not the rate at which new techniques displaced the old. He also agreed that various factors other than those considered here undoubtedly exerted some influence on the rate of imitation, e.g., factors like variation of profitability - overtime in introducing an innovation (due to technical improvement, the business cycle etc.), sales and promotional effects by the producers of new equipment and the extent of risk a firm faces in introducing an innovation. He felt that he could not deal with them because he could not find any satisfactory way to measure them.

Liao and Barker (1968) studied the factors affecting the adoption of new rice varieties in three areas in the Philippines. They broadly classified three factors as being responsible for adoption of new rice varieties: (i) physical factors, i.e., irrigation, fertiliser, (ii) economic factors, i.e., the farmer's expected yield and use of operating capital, and (iii) social factors, i.e., extension services and education.

Because of the small sample size and limited number of observations for the dependent variable, it was not possible for them to conduct a multiple regression analysis to identify the relationship between dependent and independent variables. Simple correlations have been run to provide a crude first approximation of the significance of the relationship of the specified independent variables to the adoption of new rice varieties.

The relationship between adoption and irrigation was found to be significant but no such relationship could be established between adoption and farm size. The farmer's expected yield was significantly related with the adoption. Some farmers were found to reduce the area planted to IR8 for low price and higher cost involved and insufficient irrigation but many of these farmers expressed the desire to switch over to other new varieties with better prices rather than return to local varieties. The correlation coefficient between contact with extension workers and adoption was significant the the level of education of the farmers was also found to be significantly correlated with both the rate and intensity of adoption.

Duncan (1969) studied the role of the trial stage in the adoption of superphosphate in the Clarence Valley in New South Wales. It was assumed that where a trial of a new technology on a small scale is possible, a trial stage will precede adoption and adoption is quicker where trial on a small scale is possible. In such a study the difficulty arises in deciding whether an area represents trial or actual adoption. Arbitrary percentages of total farm area fertilised were taken as indicators of trial and adoption. Duncan took a figure above 25 per cent of the total area dressed in the first year as immediate adoption.

Fron this study he concluded that different degrees of subjective uncertainty were associated with the types of soil. He also found that some distinction can be made between trial and adoption, and for those undertaking trial, the transition from trial to adoption can be distinguished. A continuous progression over time is apparent. As the new technique becomes more widely used and, consequently, as the degree of uncertainty associated with the practice is reduced, a quicker change from trial to adoption becomes more likely. Moreover, with time, the need for the trial stage appears to diminish, especially for more innovative minded farmers.

Swan (1969) studied the pattern of substitution of natural rubber by synthetic rubber among the leading rubber consuming countries of the world. He found that a graphic survey of the data indicates a consistent behaviour pattern for the share of the synthetics in the rubber market of the countries under study. The pattern gives the shape of a sigmoid (ogive) curve, which implies that the process of substitution has followed an adjustment path. Synthetic rubber consumption has increased at the expense of natural rubber because of its advantages. The introduction of a new competing raw material usually begins with experimental usage.

If it appears successful, its rate of adoption will increase as its use spreads. Eventually, an inflection point in the rate of consumption is reached beyond which the possibilities of substitution diminish enough to reduce the rate of growth of synthetic's share.

Like Griliches, and Polasek and Powell, Swan also used a logistic function instead of a cumulative normal (Gompertz) function to summarise quantitively the observed process of adjustment to synthetic rubber technology.

His logistic function may be defined in the following way:

$$(CSR/CTR)t = \frac{(CSR/CTR)*}{1 + e - (a + bt)}$$

Where: CSR = consumption of synthetic rubber in long tons

CTR = consumption of all rubber in long tons

t = time in years

a = a constant which positions the curve on the time scale

b = the rate of growth of synthetic's share of the total rubber consumption

e = 2.7183, the base of natural logarithm

* = refers to the long run equilibrium of synthetic's share of the rubber market.

The function is asymptotic to (0, CSR/CTR*) and it is symmetric around the inflection point. The rate of growth in the synthetic share of the rubber market is proportional to that already achieved and to the distance from the ceiling, or the long run equilibrium share.

The equation above can be converted into linear form which allows the estimation of the parameters a and b. If both sides of the equation divided by (CSR/CTR)* - (CSR/CTR)t and the natural logarithm is taken, the resulting linear form becomes:

$$\ln \frac{(CSR/CTR)t}{(CSR/CTR)* - (CSR/CTR)t} = a + bt$$

Application of least squares method to the above equation requires an estimation of (CSR/CTR)*, the long run equilibrium share of the market for synthetic rubber. The author has chosen the method used by Polasek and Powell to estimate the long run equilibrium.

The logistic function has been estimated by the method of least squares for nine leading rubber consuming countries of the world. For the sake of convenience the origin fixing parameter, a, has been transformed to indicate the year in which 10 per cent of the total rubber consumption was synthetic rubber. Its definition is purely arbitrary but it is designed to allow for reasonable experimentation by rubber goods producers before fully committing themselves to synthetic rubber. The transformation which yields the origin is given by the term:

$$\frac{-2.2 - a}{b}$$

The results obtained support the choice of the function. The adjusted coefficient of determination $\bar{R}^2$ is over .9 in every case; the $\bar{R}^2$ is not for the original function but for the transformed logistic function. Graphic surveys of the data support the good fit obtained.

Schluter (1971) was concerned to see whether there are differences in the rates of adoption of new seed varieties between farm size groups in India, and if so, the reasons for such differences.

He used two sets of data but both had the limitations for aggregating the individual farm observations into between five and eight farm size groups. With very few degrees of freedom a multiple regression model is unsatisfactory, so he used a linear regression model relating adoption only to farm size. A linear regression model is unsatisfactory when the dependent variable is a proportion, so the main results were confirmed using a logit model.

The linear regression model for a single farm is:

$$P_f = \alpha + \beta X_f + e_f$$

where f = farm, P is the probability of adoption, X is farm size, α and β are unknown parameters, and e is the error term and

$$E(ef) = 0$$
$$E(efef') = \delta^2 \text{ if } f = f'$$
$$= 0 \text{ if } f \neq f'$$

The outcome of whether or not a single farm adopts may be observed, but the probability of a single farm adopting may not be observed. It is possible to aggregate farms into groups, the model for the farm means becomes:

$$1/nj\ \Sigma_{f\ inj}\ P_f = \frac{1}{nj}\ \Sigma_{f\ inj}\ (\alpha + \beta X_f + e_j)$$

Where j = 1, 2, . . . , j is the farm group, grouped by the size in this analysis, nj is the number of farms in the j^{th} farm group.

The model may be rewritten as follows:

$$\bar{P} = \alpha + \beta\bar{X}_j + \bar{e}_j$$

Since all the residual covariances are zero, it follows that

$$E(\bar{e}_j) = 0$$
$$E(\bar{e}_j\bar{e}'_j) = \delta^2/nj \quad \text{if } j = j'$$
$$= 0 \quad \text{if } j \neq j'$$

Hence, the residual means are heteroscedastic, i.e., the matrix of variances and covariances of residuals is as follows:

$$\delta^2 \begin{bmatrix} 1/n & 0 \; . \; . \; . & 0 \\ 0 & 1/n_2 & 0 \\ 0 & 0 & 1/n_j \end{bmatrix}$$

The author, therefore, weighted each group mean by $\sqrt{n}$ so that the transformed residuals are homoscedastic. OLS estimates are unbiased, but do not show minimum variance if residuals are heteroscedastic.

An additional source of variation in the error term is introduced when dealing with a sample instead of the entire population. With a sample of n out of a population Nj, the model becomes:

$$\pi_j = \alpha + \beta\bar{X}_j + (\bar{e}_j + \pi_j - \bar{P}_j)$$

where π_j is the sample estimate of mean probability. Hence the residual contains a stochastic component $\bar{e}_j$, and a second term due to estimation error $(\bar{\pi}_j - \bar{P}_j)$.

The residual variance may be rewritten as follows:

$$\text{Var } (\bar{e}_j + \bar{\pi}_j - \bar{P}_j) = \frac{\delta^2}{nj} + \frac{\bar{P}_j(1-P_j)}{nj} - \Sigma_{f\ inj} \frac{(P_f - \bar{P}_j)}{nj}$$

All covariances are zero, the second term on the right hand side of this equation is the variance of binomial probability estimate, and the last term is the variance of the true probability around the mean within each group j. In this analysis, he assumed either that the second and third terms on the right hand side are approximately constant for all j, or that the first term dominates. Clearly, when the whole population is used, both the last two terms are zero.

An alternative to the simple linear model is the "logit" model. The model is:

$$\log\left[\frac{\bar{P}_j}{1-P_j}\right] = \alpha + \beta\bar{X}_j + \bar{e}_j \qquad j = \text{farm group and}$$

$$E(\bar{e}_j) = 0$$

$$E(\bar{e}_j\bar{e}_j') = \delta^2/nj \qquad \text{if } j = j'$$

$$= 0 \qquad \text{if } j \neq j'$$

The problem with respect to sampling error is similar to that considered in the preceding paragraphs. The essential difference between this and the earlier model lies in the shape of the function due to the transformation of the dependent variable in the latter. In the sample linear model, probabilities may be predicted which are similar than zero and greater than one. In the logit model all probabilities are constrained to lie between zero and one.

After analysing the data, Schluter found that the relationship between adoption and farm size varies considerably between crops, regions, seasons and over time.

Crops: The relationship between adoption and farm size is more marked in "bajra" than in rice growing areas. This is due in part to a specification problem. Income per acre is considerably higher in rice relative to bajra-growing areas. Therefore, factors related to size of farm such as credit and uncertainty may cease to be a constraint on adoption at a smaller farm size. Secondly, the increase in yield variability may be less in rice than in bajra growing areas owing to greater availability of irrigation in the former. For this reason also, uncertainty will cease to be a constraint on adoption at a smaller farm size, and differences in adoption levels between farm size groups will be less.

Wheat growing areas show a significant relationship between adoption and farm size less often than bajra and rice growing areas. In jowar growing areas, there is little relationship evident between adoption and farm size because so few farms in any size of farm group had adopted hybrid varieties.

Regions: The author found that the higher the proportion of land irrigated in a region, the higher the overall level of adoption. Even when a very high proportion of the area of all farm size groups is irrigated, as in two districts of Andhra province, differences in levels of adoption between farm size groups persist.

Seasons: In Andhra province, levels of adoption are much higher in rabi season than in Kharif season, but differences in levels of adoption between farm size groups remain the same. A greater amount of sunshine in the rabi season increases the profitability of new varieties, especially IR8.

Over time: Absolute differences in levels of adoption between farm size groups do not diminish as the mean level of adoption increases, until the limit of 100 per cent adoption on all farm size groups is approached. This means that income differentials resulting from the new varieties will persist longest in areas where overall rate of adoption is slowest.

Ray (1974) observes that there are a number of ways in which the diffusion of an innovation can be measured at a particular point of time, e.g., proportion of firms in the industry which use it or the share of output, capability, or employment of labour which it accounts for in relation to the industry's total output, capacity or employment.

Often the denominator in this fraction (the potential area of application of the new technique) is difficult or impossible to define unambiguously. In some cases a new technique may be successfully applied to a whole industry, whose limits are easy to define, but there are techniques also which are only suitable for application, at least in their early stages, to a certain type of production within an industry. Then it is necessary to decide whether to take as the relevant total product that of the whole industry, or only that part of the industry for which the technique is suitable. The farmer is more often chosen because it is frequently impossible to determine the actual range of the technique at any given point of time, or because the effects of subsequent modifications and improvements to the technique on the range of its application cannot be foreseen. The pattern of diffusion: The cumulative pattern of adopters of a new technique or the cumulative proportion of activity accounted for usually conforms quite closely to a cumulative normal distribution function or some similar rising sigmoid curve, for example, an assymmetrically skewed logistic or Gompertz type of curve. The reasons which may account for the shape of the curve are as follows: At first there have to be few pioneers to try the new innovation thus reducing the risk for those who have not introduced it; good results coming from the use of a new technique will induce other firms to introduce it; there may be a bunching of the new adoptions as part of a cyclical mechanism of the Schumpeterian type; and also, there may be time for replacement of old technology by a new technology.

He lists a number of factors which influence the incidence of innovation and the speed of diffusion, such as: (i) technical applicability, (ii) profitability, (iii) finance, (iv) size, structure and organisation, and (v) management attitude.

Ray studied the diffusion of 10 selected processes among six west European countries. As he did not have sufficient data to specify the properties of the diffusion curve which represent the share of output produced by each new technique in each country, he had to make the simplest possible assumption that the diffusion curves were linear. Neither the shape of the curve of the individual processes nor either aggregation provide any strong contradiction of this assumption.

The slope of the linear diffusion relation (i.e. the speed of diffusion) may be measured in several ways. The measurement applied for this study was the number of years taken in each country to reach Z per cent of an industry's output produced by means of each new technique. The level of Z was varied between techniques since these were different vintages and each at different stages of development.

Information on diffusion on the above basis of measurement was available for seven techniques and scatter diagrams were prepared for each of these techniques. Speed of diffusion was plotted against the time lag in introduction. For five processes the scatter diagram indicated a negative correlation between the speed of diffusion and time lag. Since the number of observations were quite small for each of the techniques, so the data for five techniques were pooled and the speed of diffusion was regressed on the time lag. The result of the pooled data also suggested a marked negative relationship between speed of diffusion and time lag in introduction. In countries which are pioneers diffusion tends to be slower. This result is consistent with the hypothesis that the pioneer faces all sorts of teething troubles. But this suggestion should be treated with caution because there were two processes which actually implied the opposite that the pioneers' diffusion was the fastest. Special circumstances affected both cases; special factors of varying importance which had to be taken into consideration when studying the diffusion process.

Barker and Anden (1975) summarised the survey results conducted in six Asian countries regarding the adoption of new rice varieties in those countries. The countries are Thailand, Philippines, India, Pakistan, Malaysia and Indonesia.

They found these factors seemed to account for differences among sample villages in those countries in relative area planted to modern rice varieties: (i) the availability of modern rice varieties for the particular locale (ii) differences in rice growing environment (including climate, soils, irrigation and drainage) and (iii) the price relationship between improved and local varieties. Although an effort was made to quantify the relationship between the adoption of new varieties and the above three factors, the results were unsatisfactory primarily because the adoption rates were very high in most of the villages that were surveyed. Taken together these three factors reflect both profitability and risk associated with the use of modern varieties. While suitability of available modern rice varieties is closely related to the environment, Government policy as it influenced price and the availability of modern varieties was a significant factor in determining the rate at which these varieties become available and were accepted by farmers.

The Program Evaluation Organisation of the Indian Planning Commission and ANU (1976) studied the HYV program in India. They found that the adoption of HYV rice is highly correlated with the size of farms. They also found that adoption of HYV rice is related to the availability of suitable HYV rice varieties for particular areas. The other most important factors found to be important in the process of adoption of HYV rice in India were avialability of water, price of fertiliser and availability of institutional credit.

CHAPTER 4

THE MODEL

4.1 Possible Forms of the Function

From the review of literature it can be assumed that the ratio of HYV rice to traditional rice varieties will increase over time and the increase will continue till it reaches an equilibrium (ceiling) point. The path of adoption thus traced out in the long run will most likely approximate a sigmoid shaped curve. Griliches (1957), Polasek and Powell (1964), and Swan (1969) established the same functional relationship through their respective empirical investigations.

If the diffusion of HYV rice follows a similar path to that shown by other new products and processes, the early period of HYV rice introduction will be a relatively slow process.

Research into the extension of information recognises five stages in the process of the adoption of new technology: (i) awareness, (ii) interest, (iii) evaluation, (iv) trial, and (v) adoption. (Jones, 1967). As Jones pointed out, where a new practice is able to be tried out on a small scale, a trial stage will usually precede adoption (Jones, ibid. p.6). Duncan (1969) attempted to show that in the case of diffusion of superphosphate use in the Clarence Valley in New South Wales, a trial stage could be distinguished from full-scale adoption. Ryan and Gross (1953) found from a survey that not one of their Iowa farmer respondents adopted hybrid seed corn without trying it on a partial basis first.

If a separate trial stage exists, it represents the first concrete evidence that a new technology is being adopted by farmers. The primary function argued for the existence of the trial stage is that by this means the farmers evaluate the worthiness of the innovation for their own particular circumstances. In the interest of understanding the adoption process more fully, and this seems to be essential if it is desired to influence the role of adoption, it is important to isolate the factors which influence adoption and the characteristics of those who innovate.

In this study, therefore, we work from the premise that a separate trial stage does exist. We attempt to isolate the factors affecting this early part of the adoption process by testing hypotheses, both in terms of the factors which are important, and those which are more important than others.

4.2 Hypotheses to be Tested

Earlier research investigating the economies of adoption seemed implicitly to recognise that there was a trial stage and that different factors may be important at this stage. Griliches (1957), Polasek and Powell (1964), and Swan (1969) took 10 per cent of the final level of adoption as the origin to allow for reasonable experimentation by users before making full commitment for its adoption.

These writers essentially tested a profit maximisation hypothesis, i.e., that the new technique was adopted first by those for whom it was expected to be most profitable. The fact that adoption did not occur at once, but was a drawn out process was explained generally in terms of the reduction of uncertainty over time. This approach recognises that widespread evaluation in use of an innovation generally reduces uncertainty over time, particularly in respect of its physical performance as, for example, the yield of new varieties of plants. Physical uncertainty is associated largely with the specific farming situation such as soil types and weather. As more and more farmers adopt the new practice, more information is available to individual farmers about the application of the new practice in different situations. As a result uncertainty surrounding the practice is reduced and its expected profitability to farmers is increased. Ultimately the level of adoption is, of course, determined in a general equilibrium sense by the interaction of factors and output prices which allows for effects of increased production on input prices and output prices.

In deriving hypotheses to test in relation to factors influencing innovators and early adopters we can draw on a number of other writings. It has been hypothesised by Schumpeter (1939) that there is a positive relationship between firm size and technological leadership. He argued that large farms are capable of undertaking the risk and uncertainty associated with innovation and in turn reduce the risk in the eyes of other firms who have so far not adopted it. Schumpeter asserted that once a firm successfully introduces an innovation, a host of others will follow.

Mansfield (1969) found from his empirical investigation that profitability, size of the firm, and size of investment for new technology are the important factors that determine the rate of adoption of a new technology.

Rogers (1962) and Jones (1967) argued that farmers will undergo a mental process at the early stage to evaluate the outcome of the adoption and in the process they will have to be aware of the new technology first to evaluate its outcome. Liao and Barker (1968) found from their study in the Philippines that adoption was higher where extension services and the rate of literacy were higher.

The HYV rice varieties require additional inputs over the traditional varieties. The increased yield from HYV rice can only be obtained with additional inputs like fertiliser and irrigation. This means the total investment costs for HYV rice are higher than for the traditional varieties, although ultimately higher yields should compensate for higher investment. So it is assumed that the availability of these two factors will influence the rate of adoption. In the first few years seed availability will be a factor that may influence the rate of adoption but in subsequent periods seeds will be produced on the farm and hence will not be limiting. However, we could not obtain adequate data on seed availability so this hypothesis could not be tested.

Since most of the farmers are subsistence farmers it may not be possible to undertake the increased investment for HYV rice because of restrictions on credit. So it is also hypothesised that availability of credit will be another factor which will influence the rate of HYV rice adoption. In the long run with the increase in farmers' income levels, the dependence on availability of credit will decrease.

The adoption models specified by researchers such as Griliches, Mansfield, and Swan have been essentially profit maximization models in which adoption is a function of profitability (or more realistically, expected profitability). Other variables have also been included to capture effects such as capital returning and risk, e.g., Mansfield's model, which also included size of firm and size of investment.

In looking at the trial stage in the diffusion process it is our hypothesis that variables other than those directly bearing on expected profitability will be more important than profitability variables. Hence, we hypothesize that factors affecting knowledge and understanding of the new technology will be of greater importance than expected profitability and variables reflecting capital rationing, risk, and the cost of other inputs. Our hypothesis is that extension and education levels will be found to be the most important in the trial stage.

Our model remains within the ambit of the profit maximization model, because factors affecting knowledge and understanding of new practices offset the profitability of the practice to a farm-firm. However, it is argued that at the trial stage, if such a stage is possible, access to capital will not be important because the need for capital in this evaluation stage is not likely to be great. In respect of risk, this is one of the factors which is being evaluated, and in a stage of little knowledge of the new technology there would be little ground on which different farmers could discriminate between innovations. This reasoning does not fly in the face of the notion that different farmers have different attitudes to risk. We are analysing the reasons why farmers in different areas undertake a trial of new farm practices at different rates. Our assumption is that within farm populations in each area there is a similar distribution of risk preference.

In our model therefore the various factors which are hypothesized to influence the rate of adoption at the early stage are listed below on a priority basis:

1. Extension
2. Literacy rate
3. Farm size
4. Fertiliser availability
5. Irrigation availability
6. Expected profitability
7. Credit availability
8. Rainfall.

It is expected that all variables will have a positive relationship with the rate of diffusion.

4.3 The Functional Form of the Model

With the available data, we decided to use a multiple regression model. The model we are concerned with is:

$$Y_{nt} = \beta_1 + \beta_2 X_{2nt} + . . . + \beta_k L_{knt} + U_{nt}$$

$$(n = 1, 2, . . . N; \quad t = 1, 2, . . . T)$$

That is the data are represented by N cross-section units over T periods of time. Y is the dependent variable, X's are the explanatory variables, and U is the error term. We have (n) = N districts and (t) = T years. So we have N x T number of observations on Y. The N x T equations can be put into compact form in matrix notation.

$$Y = \beta X + U$$

Where

$$Y = \begin{bmatrix} Y_{11} \\ Y_{12} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ Y_{1T} \\ Y_{21} \\ Y_{22} \\ \cdot \\ \cdot \\ Y_{2T} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ Y_{NT} \end{bmatrix} \qquad X = \begin{bmatrix} 1 & X11.2 & X11.3 & \cdots & X11.K \\ 1 & X12.2 & X12.3 & \cdots & X12.K \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ 1 & X1T.2 & X1T.3 & \cdots & X1T.K \\ 1 & X21.2 & X21.3 & \cdots & X21.K \\ 1 & X22.2 & X22.3 & \cdots & X22.K \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ 1 & X2T.2 & X2T.3 & \cdots & X2T.K \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ 1 & XNT.2 & XNT.3 & \cdots & XNT.K \end{bmatrix}$$

$$\beta = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \beta_K \end{bmatrix} \qquad U = \begin{bmatrix} U_{11} \\ U_{12} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ U_{1T} \\ U_{21} \\ U_{22} \\ \cdot \\ \cdot \\ U_{2T} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ U_{NT} \end{bmatrix}$$

The intercept term β_1 requires the insertion of a column of units in the X matrix. Y is a NT x 1 vector, X is a NT x K matrix, β is a K x 1 vector and U is a NT x 1 vector.

4.4 Possible Forms of Estimation

In recent years data on a large number of regions but with data on individual regions available only over a short period of time has become increasingly common in a number of different fields of economic study. Since only a few observations are available over time in our present study, but a large number of observations are available for regions at a particular point of time, it is important to make the most efficient use of the data across regions to estimate the postulated behavioural relationship. Combining cross-section and time series data substantially increases the degrees of freedom and also take into account the time factor. Hoch (1962) suggested that the use of the covariance method of analysis of combined cross-section and time series data helps avoid the problem of simultaneous equation biases existing in the time series data when there are increases in productivity over time.

In spite of the advantages involved in pooling cross-section and time series data, there are certain problems in the system with regard to the statistical method used in it. The basic idea of pooling cross-section and time series data is to obtain the estimates of some of the parameters from cross-section data, insert them in the original function, subtract from the dependent variable the terms involving the estimated parameters, and regress the residual value of the dependent variable on the remaining independent variables, obtaining estimates of the remaining parameters from the time series data. A number of studies have been done on this line by different authors like Marshak (1943), Wold and Jureen (1951), Klein (1953) and Stone (1954). Chetty (1968) has suggested that the estimates obtained from the time series data are conditional upon the estimates obtained from the cross-section data, and hence the time series regression yields only conditional estimates of the parameters. Kuh (1959) has also suggested that cross-section estimates may often be biased and as such can contaminate the combined estimates if they are introduced as point estimates.

This means that the parameters are to be estimated simultaneously from cross-section time-series data. The simplest way to estimate parameters simultaneously from cross-section and time series data is to use OLS. But Balestra and Nerlove (1966) found that the estimates obtained by the use of OLS on pooled cross-section and time series data are poor or even inconsistent with theoretical expectations. One plausible explanation for that is that when cross-section and time series data are combined in the estimation of regression equations certain "other effects" may be present in the data which should be explicitly taken into account. This can be accomplished by the assumption that the cross-sectional and/or time series data have some additive effects specific to each of them. This specific effect can be assumed to be either a constant or variable. To account for such effects, dummy variables may be introduced explicitly into the model.

In this study the parameters of the hypothesised behavioural relationship and the error distributions are unknown and the objective is to obtain the estimates of these unknown parameters on the basis of certain assumptions about the errors. The procedure adopted here to estimate the unknown parameters is the OLS method.

The desirable properties of the OLS method are its facility of estimation and the fact that OLS provides the best linear unbiased estimator if certain assumptions hold true.

These assumptions, which are taken to apply to all observations, are as follows:

1. homoscedasticity
2. non-autocorrelation
3. non-multicollinearity

The assumption of homoscedasticity implies that the variance of the disturbance term, U, is constant for all observations. If the assumption of homoscedasticity is not fulfilled, the consequence will be that we cannot conduct tests of significance and construct confidence intervals and the estimates of the coefficients will not have minimum variance. The prediction (of Y for given value of X) based on the estimated parameters, will have a high variance, i.e., prediction will be inefficient, because the variance of prediction includes the variance of U and of the parameters estimated, which are not minimal due to the incidence of heteroscedasticity. In this study, it is assumed that the variance of the disturbance term is constant for all the observations.

In regression analysis, it is assumed that the stochastic error term is an independent random variable. The error term serves as a catch-all variable and includes all effects other than the X's which are explicitly included in the regression function.

In many cases successive values of the random variable U are not independent and if the random variable in particular periods is correlated with its own preceding value (or values), there is autocorrelation or serial correlation of the random variable. With autocorrelated values of the disturbance term, if we apply OLS, the variances of parameter estimates are underestimated. Thus the reliability of the estimates is overstated, i.e., with a false smaller variance we may conclude that an estimate is reliable, which in reality is not. The variance of the disturbance term U may be seriously underestimated if U's are autocorrelated. So under that circumstance OLS will not give us the best estimate (U estimate with true minimum variance) so it is necessary to see that the assumption of serial independence of the disturbance term U is satisfied.

A modification of the Durbin-Watson test statistic for measuring autocorrelation has been used here (Webb, 1974). The formula for the test statistic is as follows:

$$d = \left[\frac{\sum_{i=1}^{n} \sum_{t=2}^{Ti} (e_{i,t} - e_{i;\, t-1})^2}{\sum_{i=1}^{n} \sum_{t=1}^{Ti} e_t^2} \right] \frac{N}{N - n+1}$$

Where N = total number of observations

n = number of time series

Ti = number of observations in time series i

$e_{i,t}$ = residual error for observation t in time series i.

This statistic provides an overall measure of autocorrelation, as opposed to estimating d for each time series in the data. The latter would be highly suspect because of the small number of time series observations.

A crucial condition for application of OLS is that the explanatory variables are not highly linearly correlated. If the explanatory variables are too highly correlated a problem of multicollinearity exists. In estimation it is the degree of multicollinearity which is important. Multicollinearity is not a condition that either exists or does not exist in functions but rather a phenomenon inherent in relationships due to the interdependence of many economic magnitudes over time.

If multicollinearity is observed the estimates of the coefficients will be indeterminate, the variance of the estimates will be large and the acceptance region for the hypothesis that a given regression coefficient is zero will be wide. In turn, this means that the power of the test is weak. Thus the test is not very useful in differentiating between true and false hypotheses. The coefficients will lack significance when the R^2 (coefficient of determination) is very high. In multiple regression analysis, it is always useful to observe the simple correlation between explanatory variables to judge the degree of multicollinearity which may be expected. If multicollinearity is detected, we should either omit one variable from the function or replace it by another variable which is a combination of both, or we can re-specify the model to neutralise the effects of multicollinearity.

Heady and Dillin (1961) suggested that if the correlation coefficients are close to plus or minus one, say greater than plus or minus 0.8, the regression analysis should be carried out with one of the highly correlated variables omitted. Which variable(s) to omit and which to retain should be decided on the basis of logic.

In this study partial correlation coefficients between independent and dependent variables were computed. The correlation coefficients between independent variables are used as an indicator of the possible presence of linear or near linear relations among the variables and such relationships can be observed in the correlation matrices.

In this study the highest positive and negative correlation coefficient among the independent variables observed is .48 in correlation matrix 1 and -.51 in correlation matrices 3 and 4. It is, therefore, concluded that multicollinearity is absent in this analysis.

In this study dummy variables were introduced to take out the year effect. A dummy variable is a variable which we construct to describe or take into account certain variation or development of the variable under consideration. We assign to it arbitrary units in such a way as to approximate as best as we can the variation in the factor which we want to express quantitatively.

In introducing dummy variables we must use one less dummy variable than the number of years otherwise we would produce linear dependence in the data matrix. An aspect of using time dummies is that the disturbance term has become region variant and time invariant. In most of the agricultural production analysis disturbances are associated greatly with regions and disturbance over time is very negligible. Mukherjee (1974) has found in his study of variation of agricultural production levels in India that 95 per cent of the variance of the total disturbances are attributed to region effects. In using this dummy variable process we have to recognise the assumption being made which emphasises the regional variation in the disturbance term.

Since regression models are simple algebraic representations of economic theory, significance tests of the results are important as to the validity of the model. The statistical tests are applied to the model to see how well the model explains the data and to examine the significance of the estimated coefficients of the variables.

TABLE 4.1

CORRELATION MATRIX 1

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	D_1
X_1	.24									
X_2	.41	-.18								
X_3	-.32	.14	-.38							
X_4	.42	.10	.39	-.25						
X_5	.75	.01	.39	.23	.27					
X_6	.51	.03	.13	.17	.23	.48				
X_7	-.01	-.14	.25	-.13	.19	-.14	-.07			
X_8	-.04	.04	.17	-.09	.25	.03	-.01	.04		
D_1	-.36	.00	.00	-.05	-.09	-.04	-.39	.00	.40	
D_2	-.10	.00	.00	-.05	-.05	-.15	-.10	.00	.06	-.50

Y (acreage) = X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8

TABLE 4.2

CORRELATION MATRIX 2

	Y	X_1	X_2	X_3	X_5	X_7	X_8	D_1	D_2
X_1	.23								
X_2	.35	-.18							
X_3	-.29	.15	-.38						
X_5	.70	.05	.37	-.23					
X_7	-.04	-.14	.25	-.14	-.17				
X_8	-.11	.08	.15	-.15	.03	.00			
D_1	-.42	.00	.00	-.03	-.11	.00	.30		
D_2	-.16	.00	.00	-.03	.01	.00	.22	-.33	
D_3	.06	.00	.00	-.03	-.08	.00	-.05	-.33	-.33

Y (acreage) = X_1, X_2, X_3, X_5, X_7, X_8

TABLE 4.3

CORRELATION MATRIX 3

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	D_1	D_2	D_3
X_1	.24											
X_2	.36	-.18										
X_3	-.45	.16	-.41									
X_4	.39	-.23	.32	-.35								
X_5	.50	-.27	.25	-.51	.33							
X_6	.26	-.02	.19	-.05	.37	.31						
X_7	.02	-.14	.25	-.15	.08	-.20	-.02					
X_8	.06	.02	.02	-.12	.32	-.03	.04	.08				
D_1	-.35	.00	.00	.00	-.15	-.02	-.26	-.00	.24			
D_2	-.24	.00	.00	.00	-.15	-.14	-.10	-.00	-.02	-.25		
D_3	.01	.00	.00	.00	-.03	.14	.25	-.00	-.41	-.25	-.25	
D_4	.32	.00	.00	.00	.05	.12	-.03	.00	.04	-.25	-.25	-.25

Y (production) = X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8

TABLE 4.4

CORRELATION MATRIX 4

	Y	X_1	X_2	X_3	X_5	X_7	X_8	D_1	D_2	D_3	D_4
X_1	.22										
X_2	.31	-.18									
X_3	-.40	.16	-.41								
X_5	.48	-.26	.25	-.51							
X_7	-.00	-.14	.25	-.15	-.21						
X_8	-.03	.05	.04	-.16	-.01	.05					
D_1	-.47	.00	.00	.00	-.06	.00	.23				
D_2	-.20	.00	.00	.00	-.01	-.00	.16	-.20			
D_3	-.11	.00	.00	.00	-.12	-.00	-.06	-.20	-.20		
D_4	.10	.00	.00	.00	.14	-.00	-.40	-.20	-.20	-.20	
D_5	.37	.00	.00	.13	-.00	-.01	-.20	-.20	-.20	-.20	-.20

Y (production) = X_1, X_2, X_3, X_5, X_7, X_8

CHAPTER 5

THE DATA

5.1 The Variables and the Regions

Bangladesh, as has already been mentioned, is almost entirely flat-surfaced with hills along the border areas of the north, south and south east. Raschid (1965) has divided Bangladesh into 20 regions with 57 sub-regions on the basis of its physical features and drainage pattern. Johnson (1957) divided Bangladesh into five divisions with 12 subdivisions on its physiographic basis. The data used in the present cross-sectional study is not based on the concept of regions as defined either by physical features or hydrological pattern or some other agro-climatic or product composition criteria. Rather it is based on 19 administrative regions, known as districts. Physical and financial farm data are only available on the district basis or the lower administrative units of the districts. There is no coincidence between natural physical divisions and administrative divisions.

Subject to the availability of data, ten variables have been used for the analysis of the diffusion of HYV rice in Bangladesh. The ten variables are listed below:

1. Acreage under HYV (as % of total rice acreage)
2. Production of HYV (as % of total rice production)
3. Number of extension agents
4. Rate of literacy
5. Size of farm
6. Acreage under irrigation
7. Fertiliser distribution
8. Institutional credit distribution

9. Expected profitability per acre
10. Rainfall.

Among the ten variables the first two were used as dependent variables in two alternative regression models and the remaining eight were used as independent variables in both regressions.

5.2 Data Sources

Data on total acreage under HYV rice and total acreage under rice are for all 19 districts for the four years from 1969-70 to 1972-73. Data on total production of HYV rice and total production of rice are also available for all districts for the six years from 1969-70 to 1974-75. Both sets of data have been collected from the Bangladesh Agricultural Development Corporation.

Data on extension agents are available for all districts for the six-year period. These data have been collected from the Bangladesh Bureau of Agricultural Statistics.

Data on literacy rate are available for all districts and have been collected from the Bangladesh Census Commission's Census Reports. The census figures for 1974 are used rather than the previous 1961 census.

The data on total acreage under irrigation and total amount of fertiliser are also available for all districts. The data series for irrigation are available for the five years from 1970-71 to 1974-75 and this includes only the area irrigated by deep tubewell, shallow tubewell and irrigation power pump. It does not include any irrigation by traditional methods.

Data series for total fertiliser distribution are available for the six-year period from 1969-70 to 1974-75. These two sets of data have been collected from the Bangladesh Agricultural Development Corporation.

Data on total availability of institutional credit are available for all districts for the five years 1970-71 to 1974-75. This set of credit data have been collected from the Central Bank of Bangladesh.

Data on the size of farms have been collected from the Agro-Economic Research Section, Ministry of Agriculture. They have collected these data from an agricultural census and the data are available for all districts for the six-year period.

Data to calculate expected profitability have been collected from various sources. Expected profitability calculations required data on average yield per acre of HYV rice and price of HYV rice, and also cost of production of HYV rice per unit. Average yield has been calculated from the data available for total production of HYV rice in each district divided by total acreage under HYV rice. National price data on HYV rice are available for the six-year period from the Directorate of Agricultural Marketing. Cost of production data have been taken from a survey report published by the Bangladesh Academy for Rural Development. Cost of production of HYV rice per unit are available for 1968 and for Comilla only.

5.3 Data Transformations

Before the regressions were run the data were subjected to the following transformations. Acreage of HYV is felt to be an appropriate measure of diffusion. However, as the data on acreage are available only for four years and production data are available for six years it was felt that production may be substitutable for acreage as an index of diffusion. So the correlation coefficient was calculated for the correlation between acreage and production over all districts and the 4 years 1969-70 to 1972-73. But no significant correlation could be established between the two variables. Ray (1974) has suggested that share of total output by new technology may also be used as a measure of diffusion. Because of the longer time series data available for production, we also used production as an index of diffusion; however, acreage would be the preferred index of diffusion.

Total acreage under HYV rice and total production of HYV rice are not an accurate guide to the extent of diffusion of HYV's since all districts differ in size and also differ in acreage under rice. The percentage figure for acreage under HYV rice will take into account total acreage under rice also. The same is true for production of HYV rice because different varieties of rice contribute differently among the districts towards total rice production. Hence, percentage of HYV rice production will give a better idea of the extent of adoption.

Since the number of farms differ among the districts, use of total number of extension agents will not yield meaningful information. So the ratio of extension agents with respect to the number of farms has been calculated.

Any farm 5 acres and above has been treated as a large farm. It was stated in Chapter 2 that the average farm size was 2.5 acres and about 77 per cent of farms are under 5 acres. Hence 5 acres seems to present a reasonable dividing line between what might be considered small and large landholders. The percentage of large farms has been used to give a better indication of variation of large farms among the districts.

Credit data has also been adjusted likewise, i.e., per farm availability of credit was calculated by dividing the total amount of farm credit by the total number of farms in the district. This gave a variation in the per farm availability of credit among the districts.

Expected profitability calculations were expected to have been the most difficult because of severe data constraints. First we found out the average per acre HYV yield in each district. Price data for HYV rice was available only for the whole of Bangladesh. The variation in the price of rice has been only minimal between the districts. Further, there has been little government interference in the free movement of rice between the districts. Hence, it was decided that the national price would be suitable for the purpose.

The per acre costs of production of HYV rice were calculated as follows: Cost data was not available either cross-sectionally or in a time series. Cost data are available for 1968 on a per unit basis (i.e., per maund, which equals 37 kg). It was assumed that like the rice price, cost of production will also not vary much between the districts because most of the inputs such as seeds, fertiliser, irrigation and credit are distributed by government agencies as a uniform price throughout the country. The only cost that may have small cross-sectional variation was labour. Most farmers use family labour and it is only for planting and harvesting that they hire labour. Farm costs and rice price are very highly correlated across Bangladesh. The main factor that caused variation in the Consumer Price Index was the price of rice. It was observed that cost of production of HYV rice has gone up with the increase in price of rice. So we decided to use the Consumer Price Index to calculate the cost of production for the subsequent years from 1968. Total cost was calculated by average yield per acre times per unit total cost of production. By deducting total cost from total revenue we obtained total profit.

In the study, our idea was to incorporate some notion of expected profitability of the HYV. As explained in the outline of the model, it is assumed that expected profitability will change with changes in uncertainty about the new technology, and changes in prices and cost associated with HYV. In an attempt to take these latter into account, an average of the six years profitability was used as a variable expressing expected profitability.

Fertiliser data have also been transformed to convert them from total amount distributed into per acre availability by dividing total amount by total acreage under rice.

The percentage of total area irrigated in each district has also been calculated to provide comparative inter-district statistics on use of irrigation water in rice farming. In respect of both fertiliser and irrigation the availability of acreage data only to 1972-73 limited the use of these two variables in the regressions.

5.4 Reliability of the Data

The accuracy of any study depends on the reliability of the data. Caution should be exercised in respect of the degree of reliability of the data before undertaking any study. All data here have been collected from public agencies which in turn have collected data in the course of their routine administration or in special investigations. Credibility of these published statistics has always been in question. They are questioned from the point of view of the methods used for collection and analysis of the primary data.

The acreage and production estimates of rice are made by a method which can best be described as a compromise between (i) the subjective method - more commonly known as the method of "eye estimation" and (ii) the objective method, i.e., the method of sample survey.

(i) The subjective method

The subjective method of estimating acreage and yield starts at the "union" (the lowest level of local government where a union consists of 10-15 villages) level. The Union Agricultural Assistant (UAA) bases his figures on the judgment of a number of farmers interviewed and adds his own observations of crop conditions in the field compared to the previous year, as well as to a normal year.

The acreage estimation for rice in any union under this system is also influenced directly or indirectly by the corresponding figures available in the 1944-45 plot to plot survey report. The yield per acre is estimated in terms of what is known as the "normal" yield rate. The term "normal" may be defined as "the average yield of an average plot in a year of average character". This system was introduced because the farmers do not understand the meaning of average and would be able to express, through intuition and long experience, the yield rate in terms of "anna" under normal conditions in their respective areas. Since farmers used to underestimate their crop yield rates for taxation and other reasons, 12 "anna" (16 anna is equal to 100 per cent) reports were considered to indicate the normal yield rate and any higher "anna" above 12 "anna" is considered as an above normal (or bumper crop) depending on the range of "anna". In the present form of subjective method, the normal yield rate has been defined for the whole country after revising the old rates wherever such revisions were thought necessary and the "anna" report has been replaced by the report in percentage of the normal. Normal yield for the country has been used as a uniform guide to all crop reporters and nothing more, keeping in view the variation in soil, fertility and weather conditions in different parts of the country.

An objective approach has been introduced since the early 1960s for yield estimates. Under this approach the UAA is required to select five farmers at random from the Union council's assessment list, and thereafter estimations based on their acreage under rice and total production are to be reported.

The UAA submits his acreage and yield estimates to the Thana Agricultural Officer (TAO). (A Thana is composed of 10-15 unions and is the lowest administrative unit in the country.) The TAO checks them in the light of his own experience and observations. The acreage under rice in the Thana is the sum of all unions' acreage and the yield is the weighted average of the union estimates.

Thana figures are transmitted to the District Agricultural Officer (DAO). He makes further checking and makes his own estimates of acreage and yield for the district in the same way it was done at the Thana level. The DAO then sends it along with the Thana figures to the Directorate of Agriculture at Dacca. These figures are examined by the Bureau of Agricultural Statistics against DAO's periodical reports on:

1. Seasonal character
2. Germination and conditions of standing crops
3. Damages, if any, due to drought, floods, cyclones, insects, pests, etc.
4. Previous years' estimates.

If any gross anomalies are found, they are referred back to the DAO concerned, for checking.

Normal yield figures are regularly revised whenever such revision is thought necessary. The annual report is expressed as a percentage of "normal".

(ii) The objective method

There are inherent weaknesses in any subjective method because they depend on personal judgment of the reporters. Since 1964-65, cluster sampling has been in use for acreage and yield estimates. Clusters have been selected in all Bangladesh and two-stage, stratified random sampling of clusters has been used.

(a) Selection of clusters - The sample "mauza" (agricultural zones) were drawn from the mauza list of Agricultural Census 1960. This census list itself has a sample of 10 per cent of mauzas in Bangladesh. The mauzas were arranged Thana-wise for all districts. Further, these mauzas were divided into seven size classes (in acres) as follows:

0 -	199
200 -	499
500 -	799
800 -	1199
1200 -	2999
3000 -	4999
5000 -	over

In selecting mauzas, probability weights were given to the size of classes. The probability of selecting a cluster in a selected mauza was adjusted in such a way that every cluster of about 5-acre size could be included in the sample with an equal probability of $\frac{1}{1000}$.

(b) The clusters - The clusters are visited six times a year and acreage under different crops in each one recorded by UAA on prescribed forms. These are submitted to TAO who checks and forwards them to DAO. The statistical staffs of the district headquarters conduct further checking of the submitted forms before sending them to the Bureau of Agricultural Statistics at Dacca.

The total acreage figures under rice are obtained by using the method of ratio estimation. For example, if xi represents the acreage observed under a crop in i^{th} cluster of size ai of a district in which there are m cluster in all, then the acreage estimate of the crop for that district is given by:

$$\frac{x_1 + x_2 + \ldots + x_m}{a_1 + a_2 + \ldots + a_m} \times \text{(area of the district, excluding forest, urban areas, under river)}$$

where xi's and ai's are random variables. The country's total acreage under rice is the sum of the individual districts acreage under rice.

(iii) Crop-cutting experiment - The yield figure of rice for each district is estimated by conducting crop-cutting experiments in plots selected from each cluster. For this purpose, one plot is selected at random out of those plots containing rice in each cluster. The logic behind this procedure can be explained by the fact that the clusters are randomly located in a district and that the probability of a crop occurring in a cluster is proportional to the intensity of its cultivation in the regions represented by the cluster.

Once the plot has been selected, a rectangular area is located at random in the selected plot for harvesting. The crop within the rectangle is harvested. The harvest is threshed and the green weight of the grain yield taken. A sample is taken by UAA for dryweight.

The yield estimate of rice in a district is made by averaging the yield obtained from the crop-cutting experiments conducted in the district. The total production of rice is estimated for each district by multiplying two estimates of acreage and yield rate. The total production of rice for the country is the sum of the district estimates.

Falcon (1961) found from his study of Punjab (Pakistan) agricultural data that area data are sufficiently accurate for most quantitative research and official yield estimates tend to vary in proportion with the deviation from an average crop. Thus, in a season of very poor crops, the official estimate is likely to overestimate the production, while in a very favourable year, the official estimate may substantially underestimate the production. The harvest price data are midway between the area and production data in terms of reliability. Bangladesh, India and Pakistan have the same statistical background, so what is true in Punjab (Pakistan) may be true to a large extent in Bangladesh also.

The data on the number of extension agents has been collected from government payroll statistics in each department concerned, so there is very little scope for discrepancy in this data.

The literacy rate has been collected from the 1974 population census (the reference date of the census is 1.3.74). The quality and accuracy of literacy data depends on how complete the census coverage was. To measure the coverage errors (persons missed from the count) a survey was conducted in April 1974. The preliminary analysis of the survey results reveal an under-enumeration of 16 per cent in four big cities (Dacca, Chittagong, Khulna and Nanayangonj) and 6 per cent in other areas. So the quality and accuracy of data on literacy should be judged also in the light of the normal errors of reporting and recording as well as misreporting and conceptual mistakes in a large scale operation like the census.

The number and the size of the farms have been collected from the 1960 agricultural census. Certain marginal changes must have occurred to the number and the size of the farms but there were no other statistics available to indicate that.

The area under irrigation and total fertiliser distribution has been collected from the records of fertiliser sale and distribution of deep-tubewells, shallow-tubewells and irrigation pumps supplied by the Bangladesh Agricultural Development Corporation as they are officially entrusted to supply these inputs to the farmers.

Credit data have been collected by the central bank from all the commercial banks, specialised banks and other government loan-giving agencies.

Therefore the above sets of data should be fairly accurate.

Price data have been collected from different important rice marketing centres in the country by the Directorate of Agricultural Marketing and the national average was calculated. Falcon's comment on price data may be correct in this respect also.

Cost data was collected by the Bangladesh Academy for Rural Development from their own survey and therefore should be accurate.

It should be noted, however, that Bangladesh was at war with Pakistan from March 1971 to December 1971 and the subsequent period after the end of the war has been marked by a relatively unstable economic situation and a major portion of the time under study happens to lie in that period.

CHAPTER 6

THE EMPIRICAL RESULTS

6.1 The Basic Model

The basic model specified in Chapter 4 is as follows:

Early diffusion of HYV rice = f (extension agents,
literacy rate,
farm size,
fertiliser availability,
irrigation availability,
expected profitability,
credit availability,
rainfall),

with the importance of the independent variables hypothesised as being in descending order as they are specified above.

6.2 The Four Sets of Estimates

Four sets of results have been estimated using OLS. The four sets of estimates are as follows:

(i) production of HYV rice as dependent variable with all independent variables for the 19 regions and for the five years 1970-71 to 1974-75 (credit and irrigation data are not available for 1969-70);

(ii) production of HYV rice as dependent variable and all independent variables, excluding credit and irrigation for reasons mentioned above, for all regions and for the six years from 1969-70 to 1974-75;

(iii) acreage under HYV rice as dependent variable and all independent variables for all regions and for the three years, 1970-71 to 1972-73 (credit and irrigation data are not available for 1969-70 and acreage under HYV rice data are not available beyond 1972-73);

(iv) acreage under HYV rice as dependent variable and all independent variables except for credit and irrigation for all regions and for the four years 1969-70 to 1972-73 (for reasons mentioned already).

6.3 Results of Expanded Profitability Model

The four sets of results of the estimated regressions are presented in Table 6.1. The significance test statistics, t, are shown alongside the estimated coefficients, $\hat{\beta}$.

With production of HYV rice as the dependent variable and excluding irrigation and credit as independent variables (equation (i)) the results show that as expected, extension services and education were significant factors in explaining diffusion. The coefficient on the fertiliser variable is also significant. The large farms coefficient has a negative sign which, though theoretically unexpected, is compatible with results obtained by Siriswasdilek and others (1975) in Thailand. They found that the adoption of HYV rice was not related to farm size in irrigated areas in Thailand. Liao and Barker (1968) also obtained the same results in their study of adoption in the Philippines. Schluter (1971), in his study of India, found that for bajra (sorghum), paddy (rice), maize and jowar, the proportion of acreage under the new rice varieties is unrelated to the size of farm. He argued that the reason why there is no positive relationship between farm size and adoption in paddy (rice) growing areas may be that adoption of new rice varieties involves a change to double cropping, so the problem of labour supervision may discourage large farms from putting a high

TABLE 6.1

REGRESSION RESULTS OF EXPANDED PROFITABILITY MODEL

	PRODUCTION OF HYV				ACREAGE UNDER HYV			
	(i) 1969-70 to 1974-75		(ii) 1970-71 to 1974-75		(iii) 1969-70 to 1972-73		(iv) 1970-71 to 1972-73	
	$\hat{\beta}$	t	$\hat{\beta}$	t	$\hat{\beta}$	t	$\hat{\beta}$	t
Extension	8.1572	8.6445*	9.1468	8.1581*	1.9794	4.8459*	2.2962	4.6275
Literacy	.5746	4.0665*	.6235	3.6730	.1225	1.8077**	.1284	1.5251
Large Farm	-.2033	-2.6784*	-.1772	-1.9318**	-.0815	-3.5839*	-.0808	-2.9525*
Irrigation	-	-	-	1.3312	-	-	.0098	.7131
Fertiliser	.0004	7.2963*	.0005	6.3392*	24.8668	8.8511*	28.5061	7.3680*
Credit	-	-	-21.7779	-.9554	-	-	1.4788	.0947
Ex. Profit	.0024	1.3395	.0032	1.5234	.0005	.5839	.0006	.6114
Rain	.0133	.6448	.0118	.4511	.0159	1.7504**	.0161	1.3332
$\bar{R}^2$	.7916		.7394		.8204		.8120	
D.F.	102		82		66		46	
d	1.74		1.85		1.83		2.55	

* Statistically significant at 1 per cent level.

** Statistically significant at 5 per cent level.

$\bar{R}^2$ Coefficient of multiple determination corrected for degrees of freedom.

D.F. Degrees of freedom.

d Modified Durbin-Watson statistic.

proportion of their rice acreage to new rice varieties. But our most plausible explanation for a negative relationship between diffusion of HYV rice in Bangladesh and large farms is that this particular new rice technology may not be suitable for large farms in a given context, whereas in a changed context a new rice technology may prove suitable for large farms. The new seed-fertiliser based rice technology with more labour absorbing capability seems to be not suitable for large farms in Bangladesh. Smith (1975) found from his study of Bangladesh that a struggling self-sufficient farmer in Bangladesh has an opportunity to triple his income from modern rice technology, so the farmer with 1.5 acres of land is much better off with new rice technology and can be expected to re-invest very modestly.

The very low coefficient for fertiliser is explained by the nature of the data. In this regression we have used the absolute amount of fertiliser rather than the per acre availability of fertiliser. The reasons for use of the data have been explained in Chapter 5.

Expected profitability and rain are not statistically significant, but nonetheless, they all have positive signs, as expected.

With the same dependent variable the second set of estimations, equation (ii) which includes all independent variables, gives similar results. The credit coefficient has a negative sign but it is statistically non-significant. The coefficient for irrigation is very small and non-significant. The reason we did not get any statistically significant relationship between irrigation the the rate of diffusion may be because of the nature of the available data used in the analysis or it may be due to an increased shift from HYV rice grown under mechanised irrigation to HYV rice grown under rainfed conditions.

With acreage as the dependent variable, equations (iii) and (iv), the significance of the regression coefficients is largely unchanged except that the coefficient on the literacy variable is only significant at the 5 per cent level or greater.

The rainfall variable is significant in equation (iii) at the 5 per cent level, with the sign positive as hypothesised.

The model tested in this study was described as being an "expanded" profitability model, that is, it tries to capture the effects of factors which affect profitability but which are difficult to incorporate in a measure of the usual factors affecting profitability such as yield, prices and costs. It is part of the test of our hypothesis that the extra factors are more important than the so-called normal profitability variable. Hence, we also wished to test a basic profitability model to see how it performed by comparison with our expanded model.

6.4 Results of Profitability Model

We ran two separate regressions with two different dependent variables (production of HYV rice and acreage under HYV rice) and expected profitability as the only independent variable in both regressions. The results obtained are shown in Table 6.2.

TABLE 6.2

REGRESSION RESULTS OF PROFITABILITY MODEL

	Production of HYV		Acreage under HYV	
	$\hat{\beta}$	t	$\hat{\beta}$	t
Ex. profit	-.1869	-.0570	-3.9268	-.3894
$\bar{R}^2$	.0367		.0541	
D.F.	109		71	
d	.43		.73	

In both regressions the coefficient for expected profitability had a negative sign and both coefficients are statistically non-significant. $\bar{R}^2$ is also very low, indicating that expected profitability explains little of the variation in the dependent variable.

6.5 Beta-weight Results

Finally, to test our hypothesis about the relative importance of the various factors in the early stage of diffusion of HYV rice, we have used "beta-weight coefficients", the formula of which is given below (Goldberger, 1964):

$$\text{Beta-weight} = \hat{b}j \, \frac{\sigma(xj)}{\sigma(y)}$$

Beta weights provide an indicator of the amount of variation of the dependent variable explained by each independent variable. The results obtained using the above formula are presented in Table 6.3.

The results in Table 6.3 give a large measure of support to our hypothesis with production of HYV rice as the dependent variable extension services, education and farm size are most important. With acreage under HYV as the dependent variable, fertiliser, extension services, farm size, education and rainfall are most important in explaining variation.

TABLE 6.3

BETA-WEIGHT RESULTS

	PRODUCTION OF HYV		ACREAGE UNDER HYV	
	1969-70 to 1974-75	1970-71 to 1974-75	1969-70 to 1972-73	1970-71 to 1972-73
Extension	.40	.47	.25	.28
Literacy	.20	.23	.11	.11
Large Farm	.15	.14	.19	.20
Fertiliser	–	–	.51	.57
Irrigation	–	–	–	.05
Credit	–	–	–	–
Ex. Profit	.06	.09	.03	.04
Rain	.03	.03	.10	.10

CHAPTER 7

CONCLUSIONS

In the light of the chronic foodgrain shortage in Bangladesh, it was felt that reliance on traditional rice cultivation would do little towards solving the problem. The application of new knowledge resulting from science and technology to traditional agriculture has begun to show dramatic results in many countries. The new rice technology has opened the possibilities of greatly increased production and also offers an opportunity to break the chains of rural poverty in Asian countries including Bangladesh, which was not far behind other countries in introducing the new rice technology. Success will depend upon how well this opportunity is availed, which in turn depends upon how well a particular society is conscious about the consequences of the new technology. This technological breakthrough in rice production is believed to have opened the opportunity for foodgrain self-sufficiency in the near future in Bangladesh. Whether this goal is realised greatly depends on how rapidly this new rice technology will be diffused in Bangladesh.

The government of Bangladesh in the First Five Year Plan (1973-78) outlined two broad stretegies to be employed to increase production of foodgrain to reach self-sufficiency by 1977-78: (i) increase in yield to be obtained by introducing HYV rice; (ii) increase in cropped area by multiple cropping, made possible by irrigation. The hard core program which has been identified for rapid expansion of HYV rice in Bangladesh under the First Five Year Plan includes the use of agricultural inputs - fertiliser, pesticide and seeds along with irrigation.

On the basis of these targets an estimated need of major agricultural inputs and the approximate cost involved therein have been worked out.

In this study an effort has been made to look into the diffusion of HYV rice in Bangladesh. Both the tabular and the graphic representation of data show adoption of high yielding rice varieties to be at an early stage in the diffusion process. The rate of diffusion of HYV rice in Bangladesh is much behind many rice producing and consuming countries of Asia. The present study has attempted to provide a quantitative measure of the factors influencing the diffusion at an early stage and offers some guidlines for policy. However, the analysis is subject to a number of limitations and the results therefore should be considered in that light.

Most of the limitations relate to the availability and nature of data used in the study. These limitations were discussed in Chapter 5 in detail. Because of the lack of data we could not test the suggested hypotheses by alternative estimation methods (e.g., error components model, logistic function). However, it may be argued that the model employed here seems to be appropriate in an analysis of the present problem and the results, as far as they go, do support the hypotheses strongly.

To study the early phase of diffusion of HYV rice to Bangladesh an expanded profitability model has been constructed. It was hypothesised that where trial is possible on a small scale in the adoption of a new technology, the trial stage will precede the adoption stage. It has been suggested that a trial stage is more likely where the innovation is able to be tested on a small scale. Duncan (1969) has shown that it is possible empirically to distinguish a trial stage in the adoption process. This trial stage is the first positive indication that the farmer is in the process of adopting the new rice technology. It seems to be of utmost importance to study this trial stage because the ultimate rate of diffusion will depend upon the results obtained from the trial stage.

It is hypothesised that the factors of major influence in the trial stage will not be the same as the factors important in the adoption stage. Comprehensive dissemination of information regarding new technology to farmers is hypothesised to be the crucial element in the early stage of diffusion. If this is so, the extension services and education variables are thus more important at the trial stage than at the adoption stage. It is hypothesised that these factors will be more important than variables explicitly seen as affecting profit such as prices of output and costs of inputs. Liao and Barker (1968) found that extension service and education variables are very important factors at the early stage of adoption of HYV rice in the Philippines. Eventually, as Duncan (1969) has suggested, the trial phase loses its importance as diffusion becomes more widespread.

The major burden of this study was the estimation of parameters from cross-section and time series data. Pooling cross-section and time series data has become increasingly common in many economic studies in recent years. This helps to increase the degrees of freedom and also takes into account the time element. In spite of its advantages, there are certain problems associated with the statistical techniques employed for estimating parameters from combined cross-section and time series data. Here, after giving due consideration to estimation of the parameters with efficiency and consistency and also keeping in view the limitations with the available data, we have decided to use OLS to estimate the parameters. OLS gives best linear unbiased estimate of the parameters if the assumptions hold true.

The empirical findings of the study strongly supported the assumptions made about factors important in the early stage of diffusion. The coefficients for extension agents, education, large farm and fertiliser are all statistically significant in the four regressions, except for the education coefficient which is statistically non-significant in one of the regressions. The results of our empirical findings confirmed our hypothesis that dissemination of information regarding new technology, as captured in the extension and education variables, is the crucial factor in the diffusion process at the early stage. The significance of the coefficient on the fertiliser variable is also consistent with the prevailing situation in Bangladesh. New rice varieties have been found to be most responsive to fertiliser use among the supplementary inputs. Irrigation, credit, and expected profitability were statistically non-significant, as was rainfall except in one of the four regressions. The statistically non-significant very low coefficient of irrigation seems to be due to the nature of data used in the analysis or it may be due to a changing emphasis on growing more HYV rice under rainfed conditions. However, keeping in view the agronomic requirements of HYV rice and the tabular observation of the relationship between acreage under HYV rice and irrigation in Chapter II, this result should be treated with caution.

We did not find a positive relationship between the rate of diffusion and the number of large farms as expected on the basis of the argument that owners of large farms are more willing to face the risk of trying new ideas. In fact, we obtained a negative relationship. Plausible reasons for the negative relationship found may be attributed to the problems associated with supervision of large labour inputs required for modern rice technology as suggested by Schluter (1971). Another reason is that modern rice technology in its present form may not be very suitable for large farms in Bangladesh. Smith (1975) found that small farmers in Bangladesh are proportionately benefitted with large farms in increasing their income from modern rice technology and this has led to more small farmers participating in modern rice cultivation.

However, we cannot satisfactorily explain this finding and it poses an interesting problem for further research.

A further test of our hypothesis, which will only be possible when HYV rice has been adopted for a large number of years, is whether in the later stages of the adoption process the expected profitability variable is more or less important than our dissemination variables.

Increases in agricultural output have been forecast by the planning authority on the basis of schematic tables of coefficients that give expected increases in output as a result of increases in specific inputs. In reality projected output repeatedly differs widely from actual output.

This seems consistent with the findings of the present study which suggest that the provision of inputs other than fertiliser have been unimportant in explaining the diffusion of HYV rice. Our results show that efforts to diffuse HYV rice in Bangladesh are likely to pay off if directed to such desired areas like expanding the extension services both in quality and quantity, spread of education and distribution of fertiliser in proper quantity and at proper time.

The basic argument in this thesis is that the early stage of diffusion of HYV rice in Bangladesh is dependent primarily on dissemination of information regarding HYV rice. From our study it appears that to speed up diffusion of HYV rice in Bangladesh the extension service should be extended so that the technical and other information can be made available to farmers more efficiently. The spread of education will help the farmers grasp the intricate technicalities involved in new rice technology at their personal level through journals and bulletins. The dissemination of information can be divided into long term and short term perspectives. Since investment in education is a long term aspect, emphasis should be put more on the short term aspect, i.e., expansion of extension services. In a long run perspective of looking towards other introductions of new agricultural technology investment in education should be geared up. New rice technology needs new farm skills and expertise of a higher order than was needed with traditional methods of cultivation. The agronomic requirements are quite different as regards planting dates and planting depths, fertiliser rates and timing, insecticide, pesticide, and fungicide applications, watering and many other factors. Unless appropriate extension measures are taken in the short run to educate the farmers with respect to these complexities neither higher yields will be obtained nor will adoption be rapid.

The person who establishes direct contact with farmers in Bangladesh is the Union Agricultural Assistant (UAA). The average load of an individual UAA is from 1,000 to 1,200 farm families. The physical facilities available to him are negligible. Some of the UAA have a two-year diploma in agriculture but the majority of them have only in-service and job-oriented training. No facility exists for training farmers in crop orientation programs. The UAA faces a heterogeneous clientele constituted of absentee landholders, share-croppers and landless peasants. This has been further complicated by the poor income and large scale illiteracy of the farmers. The tasks faced by an extension agent under present circumstances are simply enormous. A new rice variety with great promise may be released but the processes required for the acceptance by the clientele are complex. The acquired and conceived knowledge of evolving a new variety is required to be interpreted by the extension agents in the light of the level of understanding of clientele for which the flow of information should be continuous in the early stage of adoption. To make the extension service more effective the average work load of an UAA should be reduced to a desirable level where he can most effectively use his technical expertise.

In the long run, the heavy pressure on extension agents can be reduced to a great extent by spreading education. Investment in education will only pay off in the long run because of its long gestation period. Spread of education will have the effect of farmers themselves being able to understand by reading agricultural journals and bulletins and also their level of understanding will be improved.

Our empirical findings also suggest that the rate of diffusion is responsive to fertiliser distribution, so the availability of fertiliser to keep pace with the spread of HYV rice in Bangladesh both in short and long run should have to be taken into consideration. Foreign exchange requirements for the import of fertiliser seems to be a hurdle in obtaining fertiliser in the required amount. The government will have to be careful about its socio-economic priorities in allocating foreign exchange for fertiliser import.

Other factors of which we could not make any quantitative analysis are touched on here in some length because it is considered that these factors bear certain social and economic implications in the process of diffusion of HYV rice in Bangladesh.

There is a sizeable number of share-croppers in Bangladesh. They have no defined legal position in the country. The impact of share-cropping on diffusion of HYV rice needs to be carefully studied. Theoretically, share-croppers have very little incentive to increase production with increased investment in HYV rice, since this increased production will increase the share of the land owner without his (the land owner) corresponding contribution to increased costs. In Bangladesh, it is estimated that 11 per cent of the farmers are share-croppers and 4 per cent are owners-cum-share croppers-cum-labourers.

It is natural that without a clear legalposition for share-croppers, a sizeable number of the farmers may be left without any incentive to adopt new rice technology.

HYV rice is very environment specific. Its diffusion will be greatly influenced by how rapidly the research organisations are capable of making available environment-specific varieties for different agro-climatic regions. This, in turn, raises the question of how the government is going to finance these kinds of research efforts. To date, all HYV rice used in Bangladesh have been dwarf or semi-dwarf transplanted varieties susceptible to problems when used in deeply flooded areas or as dry crops. There are three major rice crops in Bangladesh, each with quite different suitability to introduction of short stemmed HYV rice. The speed of diffusion will depend in future on the evolution of seeds suitable for regions or components of a region such as deep water, rainfed and dry season HYV rice varieties with different topographical and soil formations. Intensive research will be needed to solve these problems.

It is suggested therefore that a sustained policy of research in specific regions as to their geo-climatic and socio-economic characteristics is essential for diffusion of HYV rince in Bangladesh. The research in modern rice technology should also be geared to obtain good yield potential and reasonable yield stability. More research is also required to find out new rice varieties where dependence on fertiliser and water is less, as the construction of water control systems and import of fertiliser have been found to put much pressure on scarce foreign exchange in Bangladesh. New rice varieties should have the quality to make them disease and pest resistant and this will lessen the burden on scarce foreign exchange from imported chemicals.

Meanwhile, it should be borne in mind that as has already been observed in many parts of the world, diffusion of new rice technology must be accompanied by a whole range of activities designed to provide farmers with needed information and access to inputs.

The potentials, limitations and consequences of new rice varieties are becoming more and more clearly defined with the passage of time. While HYV rice has contributed very significantly to the increase in rice production, it is by no means the whole source of productivity gain in Bangladesh agriculture. Productivity gains realised in rice production are associated with HYV rice but a significant portion of the growth is equally accounted for by indigenous research discoveries.

A set of new problems are expected to arise with the spread of new rice technology, whatever its speed, which need to be foreseen and acted upon now.

One of the most important effects of HYV rice is the change in cropping pattern which has been brought about sometimes in combination with irrigation. Double, even triple, cropping has become a part of the adopting process for HYV rice in Bangladesh. In many places double cropping of rice has been undertaken by replacing production of vegetables and pulses in Bangladesh and consequences of such replacement should be viewed from the point of overall nutritional deficiencies. The short maturity of HYV rice rather than higher yields may be a most important aspect to farmers. This intensive cropping has both good and bad sides. Intensive cropping may accentuate the already existing disease and pest problems but this also helps to use more and more labour and makes a more evenly distributed labour demand throughout the year thus enhancing prospects for the landless farm labourers.

Serious doubts have been expressed about the ability of the existing marketing system to cope with the increased production. Storage facilities and transport are inadequate and crop grading is often deficient in Bangladesh.

To sum up, the broad implications of the present study seem to be one of optimism. The existing structure of agriculture in Bangladesh would seem to be responsive to an increase in factors which should accelerate the diffusion of HYV rice in Bangladesh. Meanwhile, consideration should be given to the up-grading of a whole range of policies to sustain the speed of diffusion of HYV rice.

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A P P E N D I X   A

DISTRICT-WISE RATE OF DIFFUSION OF HIGH YIELDING VARIETIES OF RICE IN BANGLADESH

PERCENTAGE OF ACREAGE UNDER HYV RICE

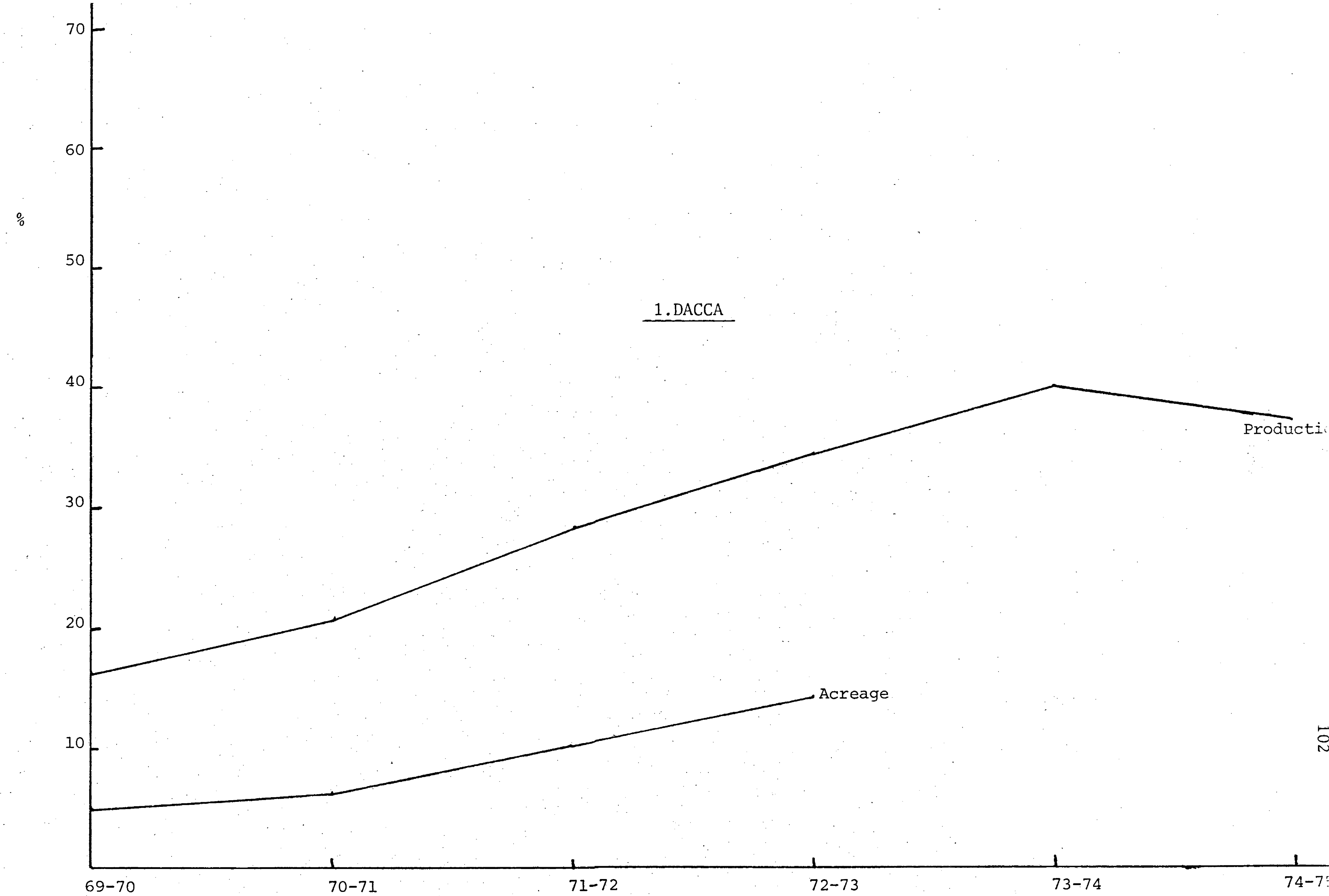
DISTRICT	1969-70	1970-71	1971-72	1972-73
Dacca	5.03	6.77	10.67	14.36
Mymensingh	3.00	5.13	8.03	14.00
Tangail	–	–	–	–
Faridpur	0.88	2.32	2.53	2.87
Chittagong	9.24	16.18	21.71	29.14
Chittagong Hill Tracts	6.34	6.71	13.44	18.77
Noakhali	2.90	4.68	6.84	10.71
Comilla	5.37	7.33	9.08	14.61
Sylhet	2.61	3.58	4.56	11.70
Rajshali	1.01	1.48	2.77	4.85
Dinajpur	1.23	3.60	2.88	12.71
Rangpur	0.88	1.99	5.75	8.65
Bogra	0.94	3.87	6.84	12.62
Pabna	0.89	1.54	2.31	4.51
Khulna	1.06	2.62	4.31	8.32
Borisal	2.88	7.73	9.53	13.91
Patuakhali	–	6.39	8.86	10.91
Jessore	1.46	2.75	2.60	5.05
Kushtia	0.49	3.48	3.19	6.80

SHARE OF HYV RICE IN TOTAL RICE PRODUCTION

DISTRICT	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75
Dacca	16.49	20.80	28.42	34.72	40.14	37.71
Mymensingh	7.88	14.86	21.21	30.96	35.99	38.82
Tangail	-	18.13	11.68	20.22	25.55	23.29
Faridpur	4.40	11.02	12.12	13.28	13.62	15.03
Chittagong	20.98	34.72	38.08	50.38	58.87	60.05
Chittagong Hill Tracts	15.75	18.87	26.86	38.43	46.72	61.65
Noakhali	10.15	16.13	20.98	25.17	43.29	45.78
Comilla	14.15	19.40	21.18	28.97	47.19	48.81
Sylhet	6.53	8.85	10.41	23.17	29.17	32.51
Rajshali	3.23	3.95	8.33	13.07	21.21	19.36
Dinajpur	2.69	8.11	6.70	25.98	44.10	23.69
Rangpur	2.70	4.44	14.28	16.18	29.76	21.48
Bogra	3.11	9.51	17.46	21.34	33.60	23.29
Pabna	3.00	6.54	9.41	14.31	26.31	21.09
Khulna	3.88	11.09	14.67	16.10	14.65	16.92
Barisal	7.47	28.87	30.08	29.63	41.22	40.09
Patuakhali	-	29.95	23.77	27.28	32.35	23.22
Jessore	5.30	9.79	8.73	12.47	14.88	15.00
Kushtia	2.00	11.35	14.81	18.01	16.42	15.05

A P P E N D I X B

DISTRICT-WISE GRAPHIC REPRESENTATION OF THE RATE OF DIFFUSION OF HYV RICE IN BANGLADESH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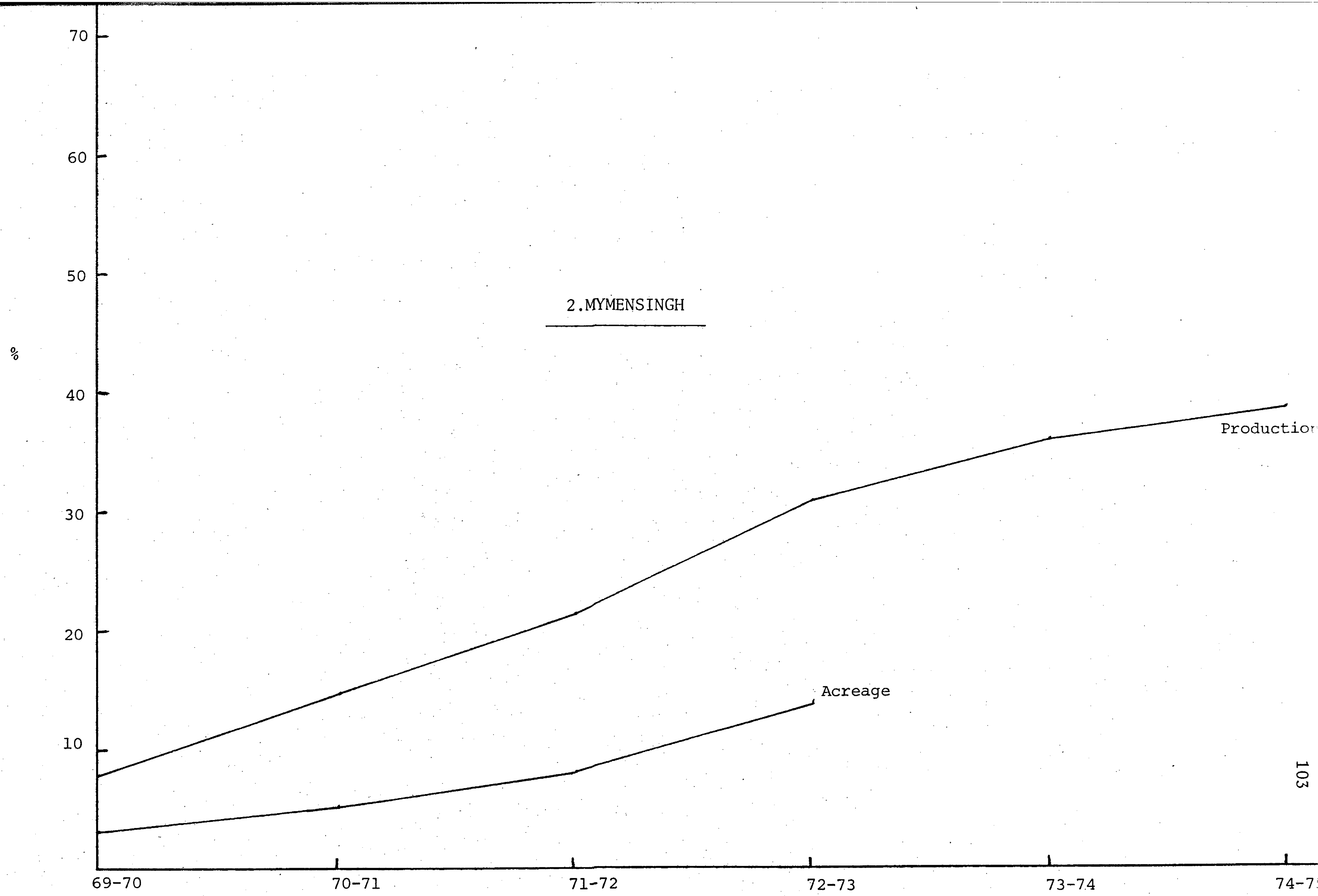
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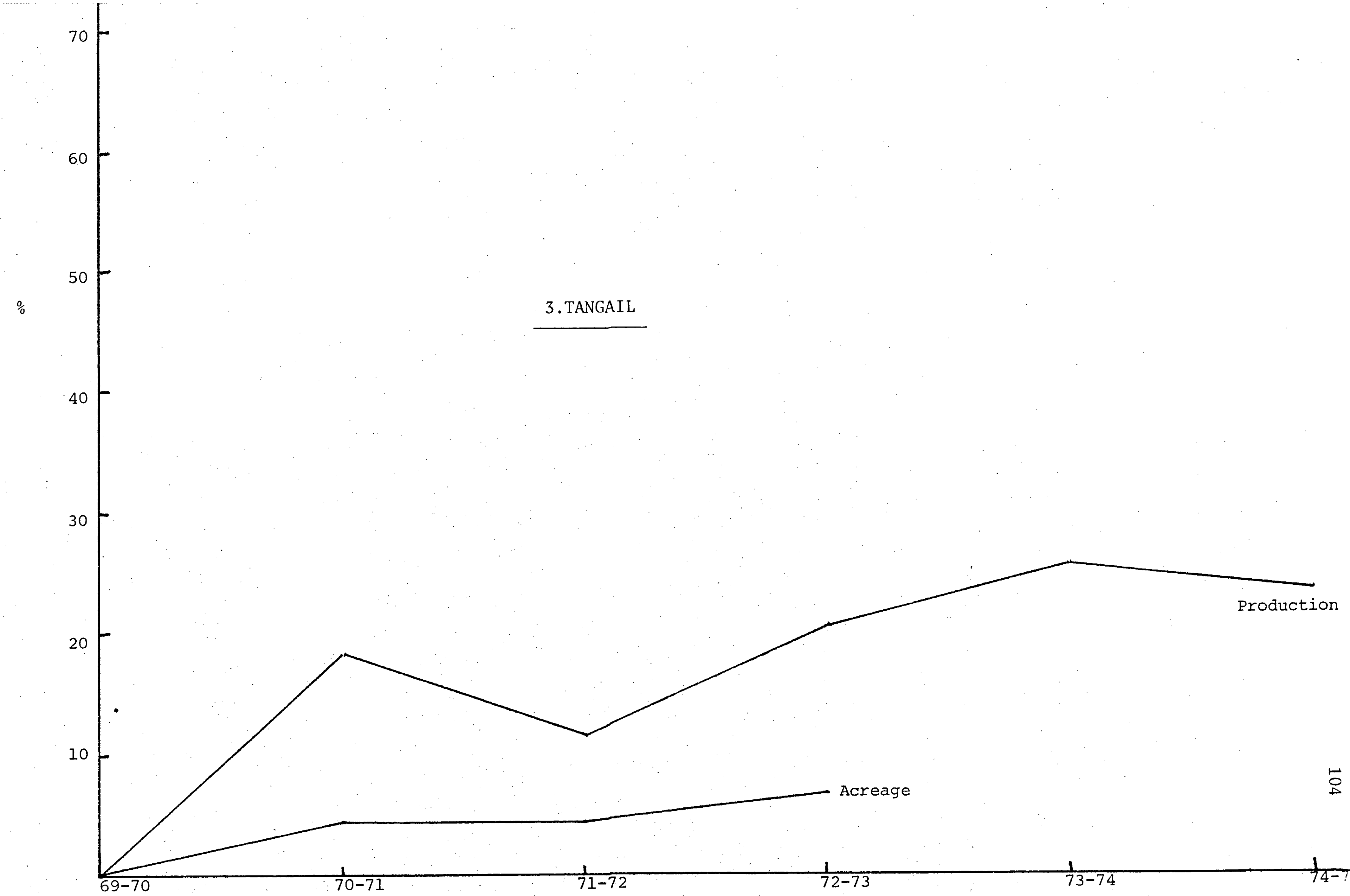
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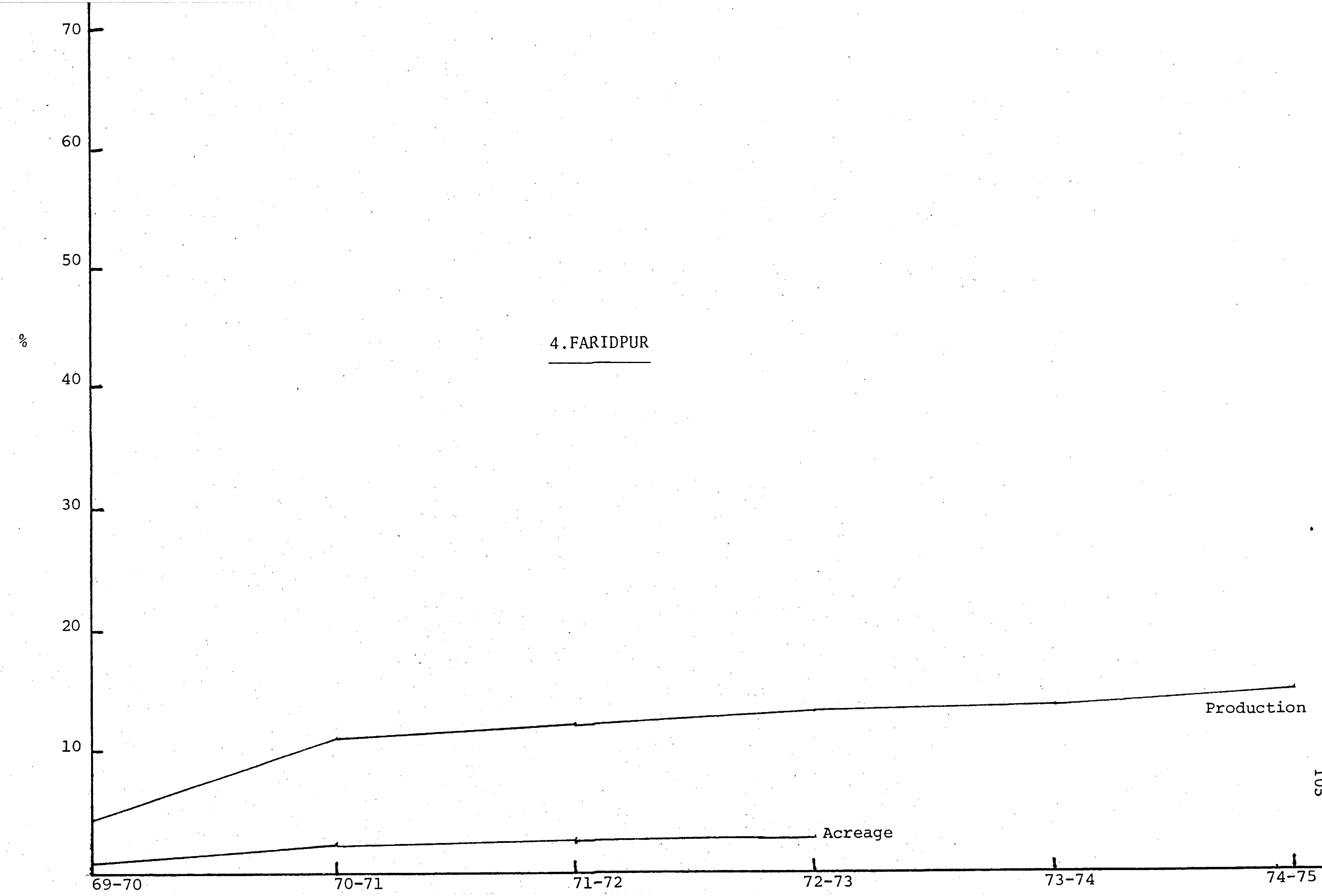
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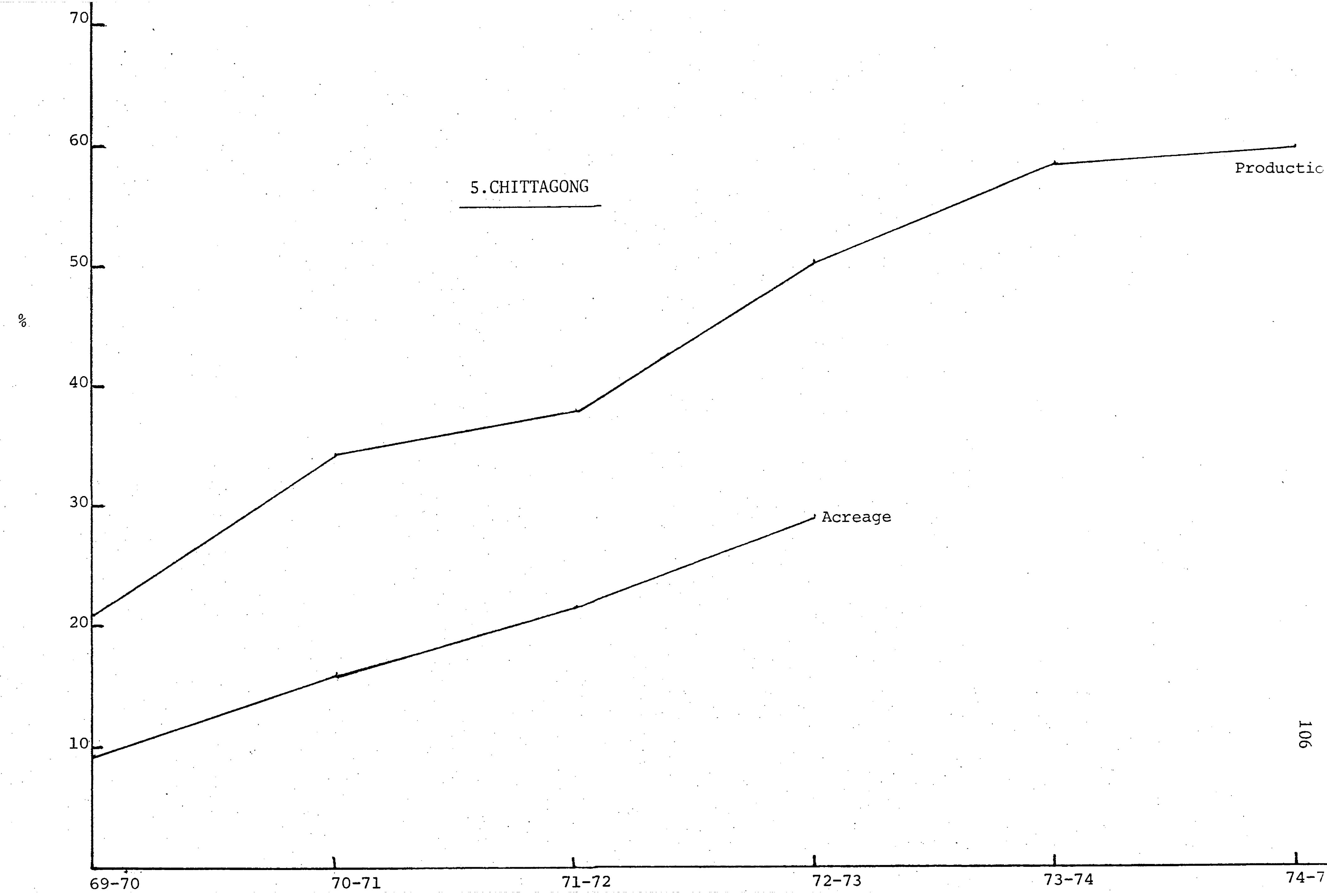
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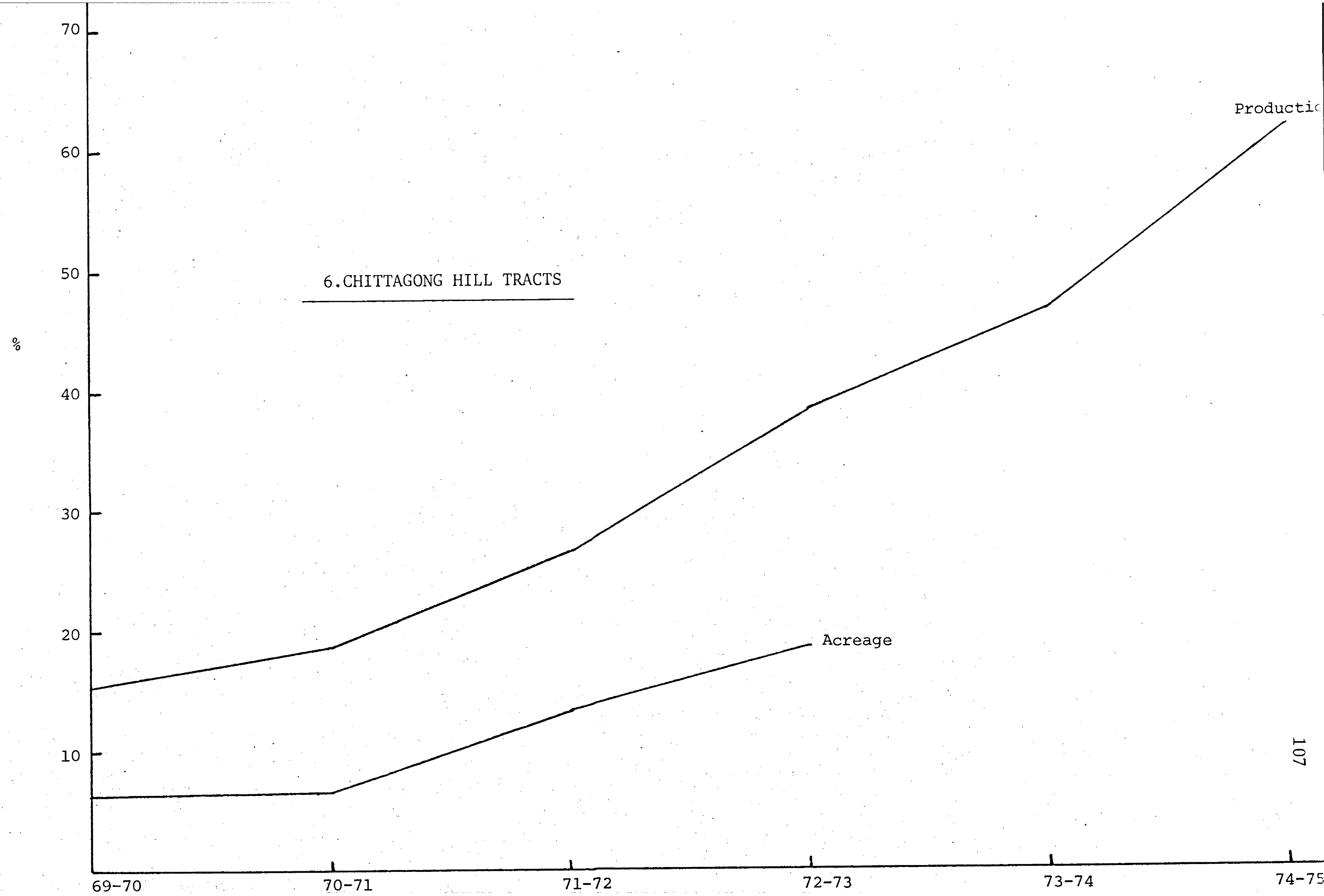

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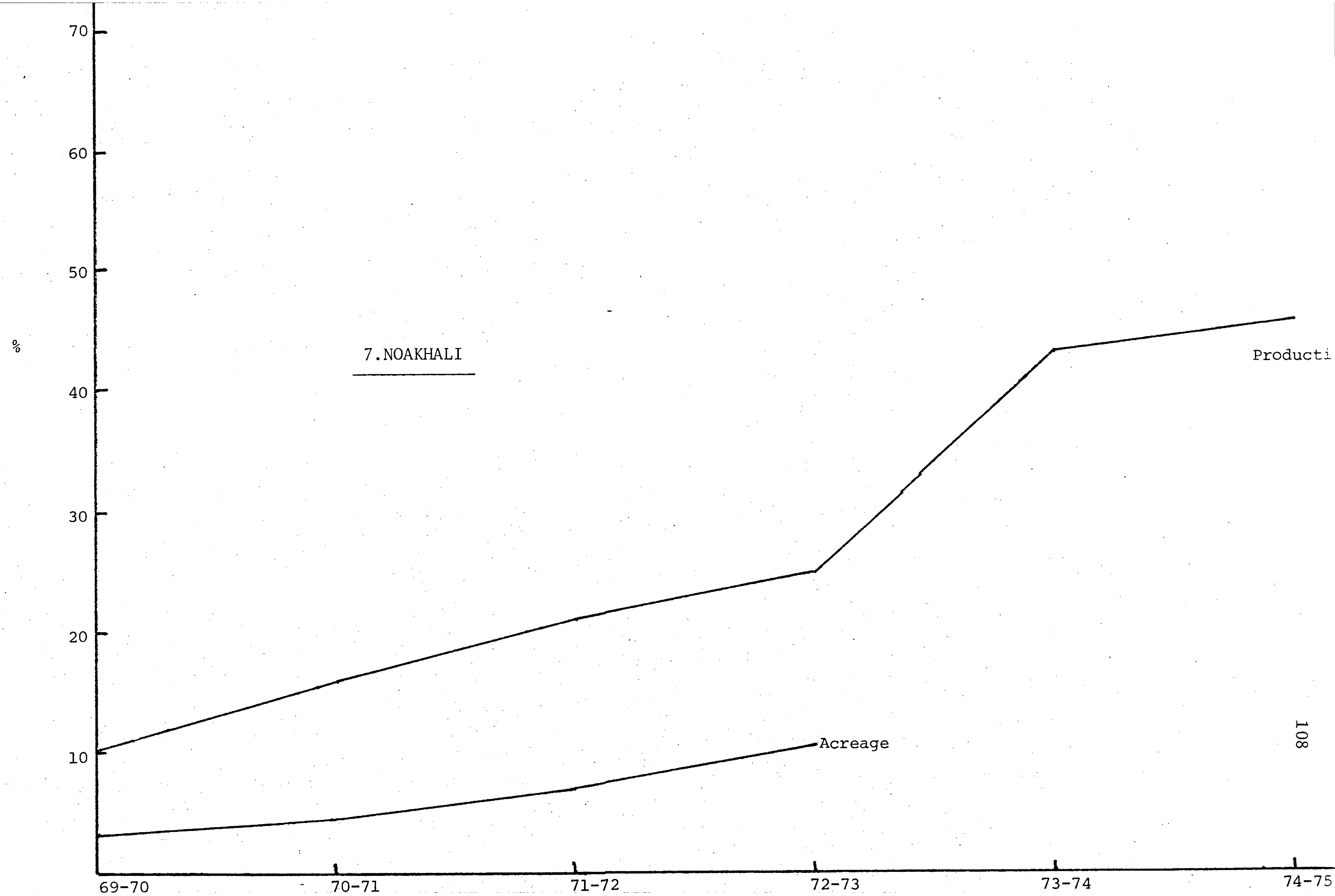

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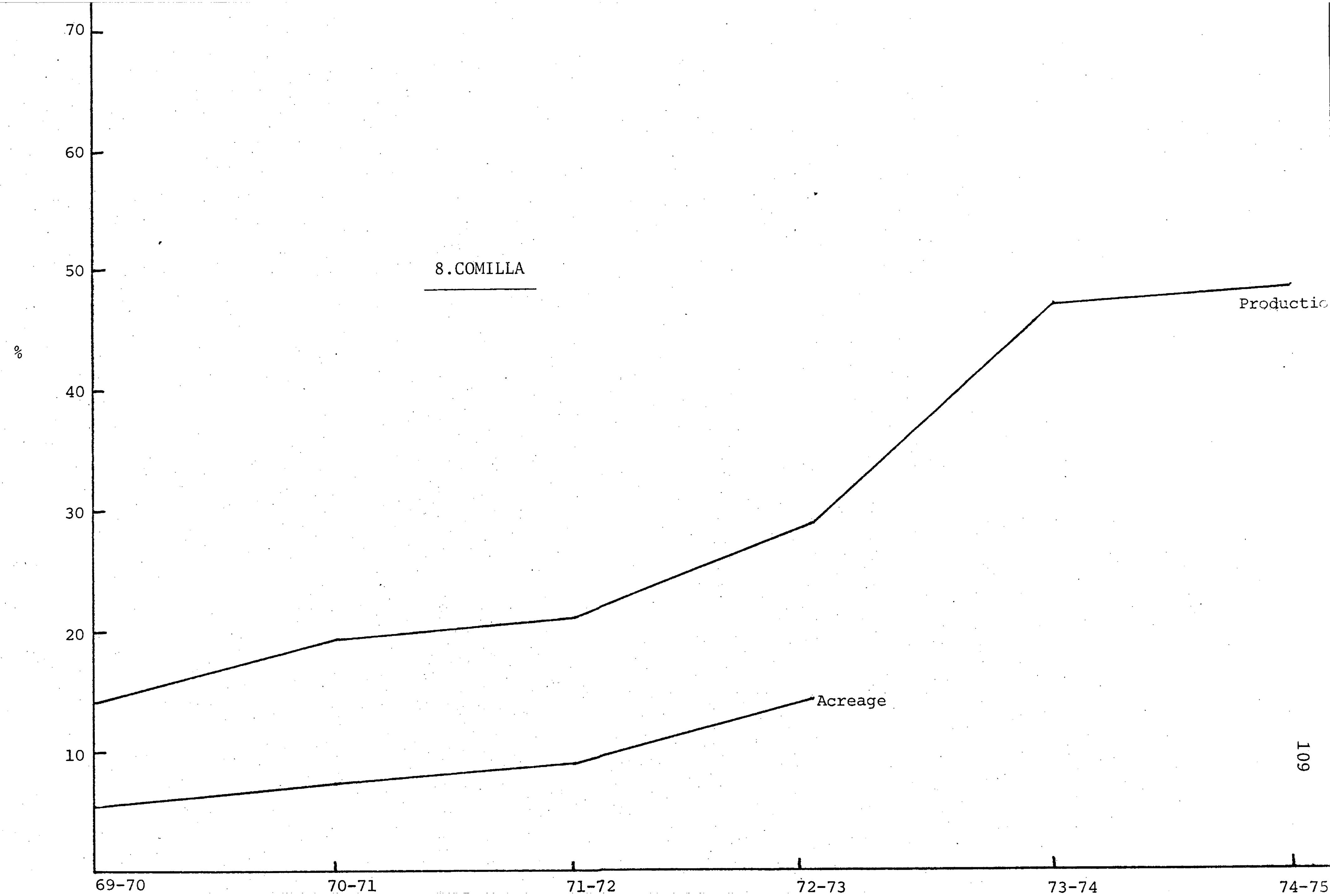
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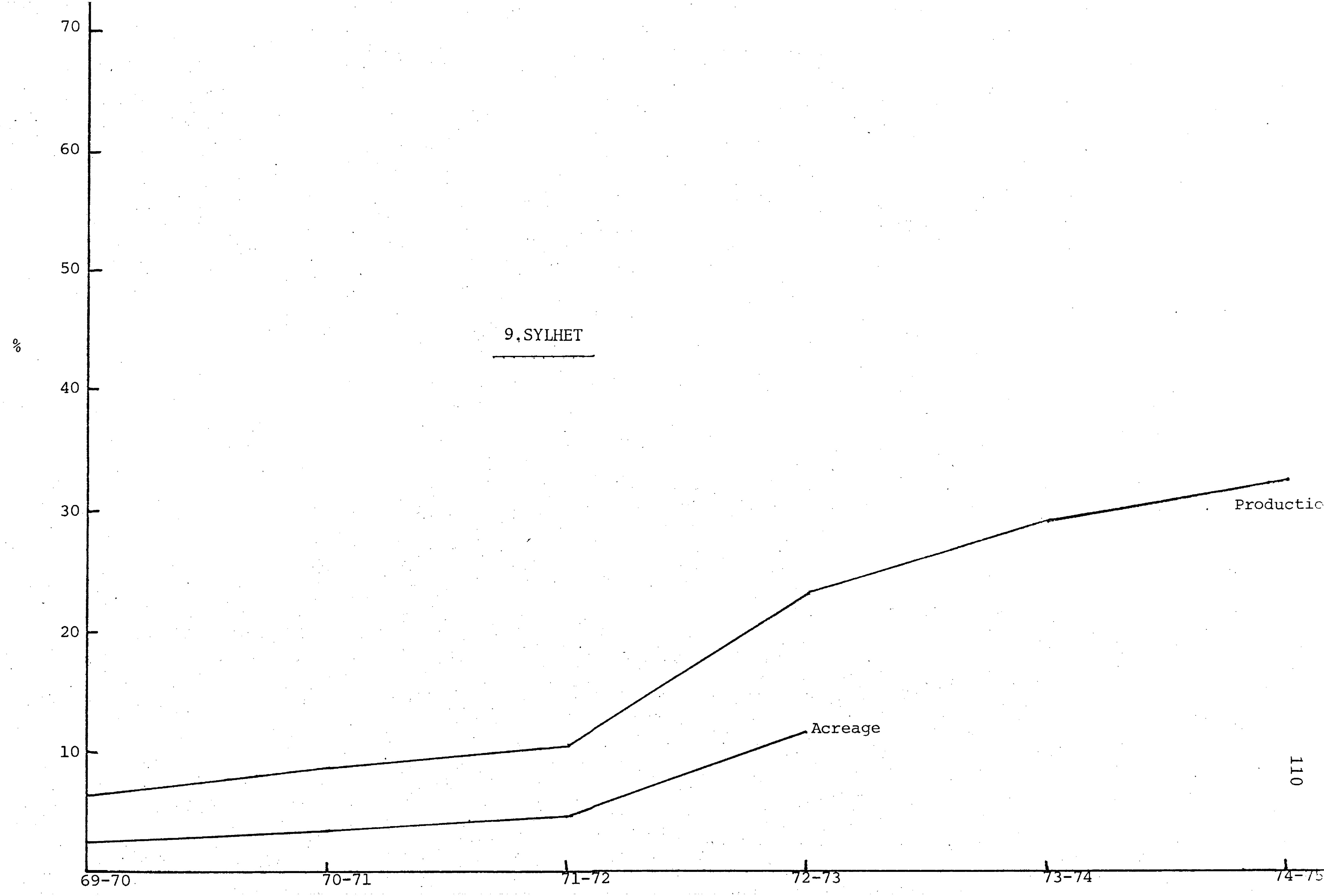
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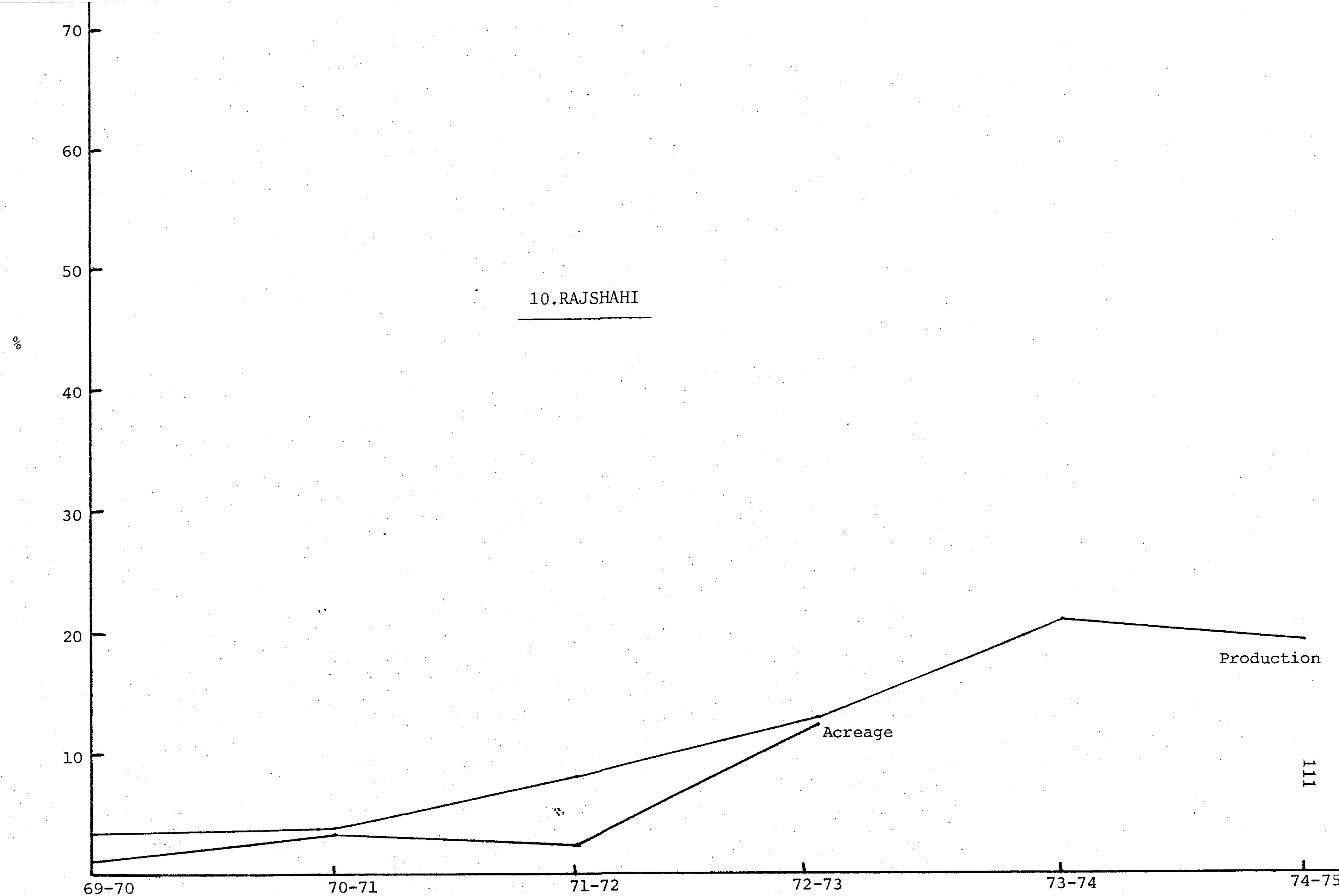
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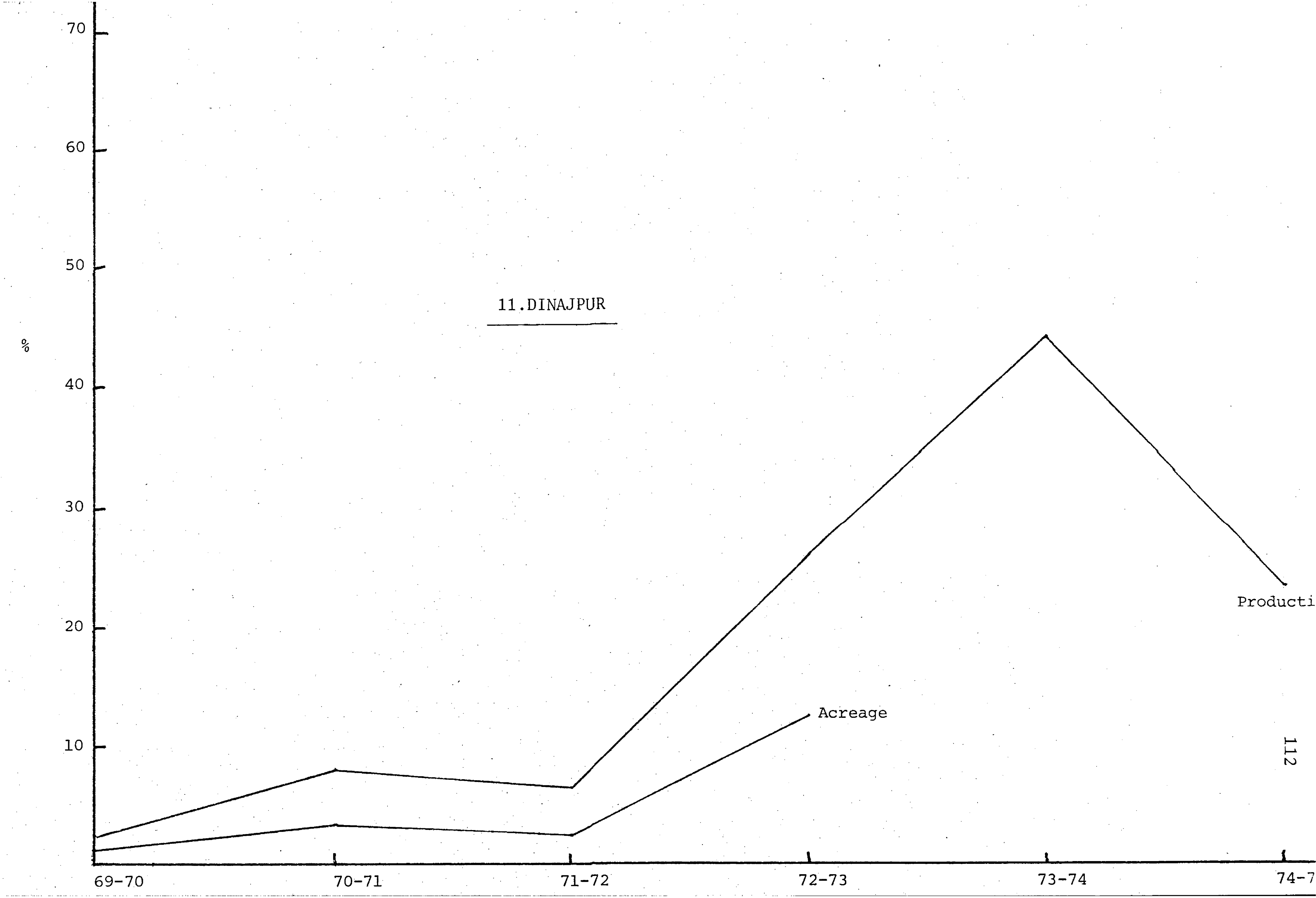
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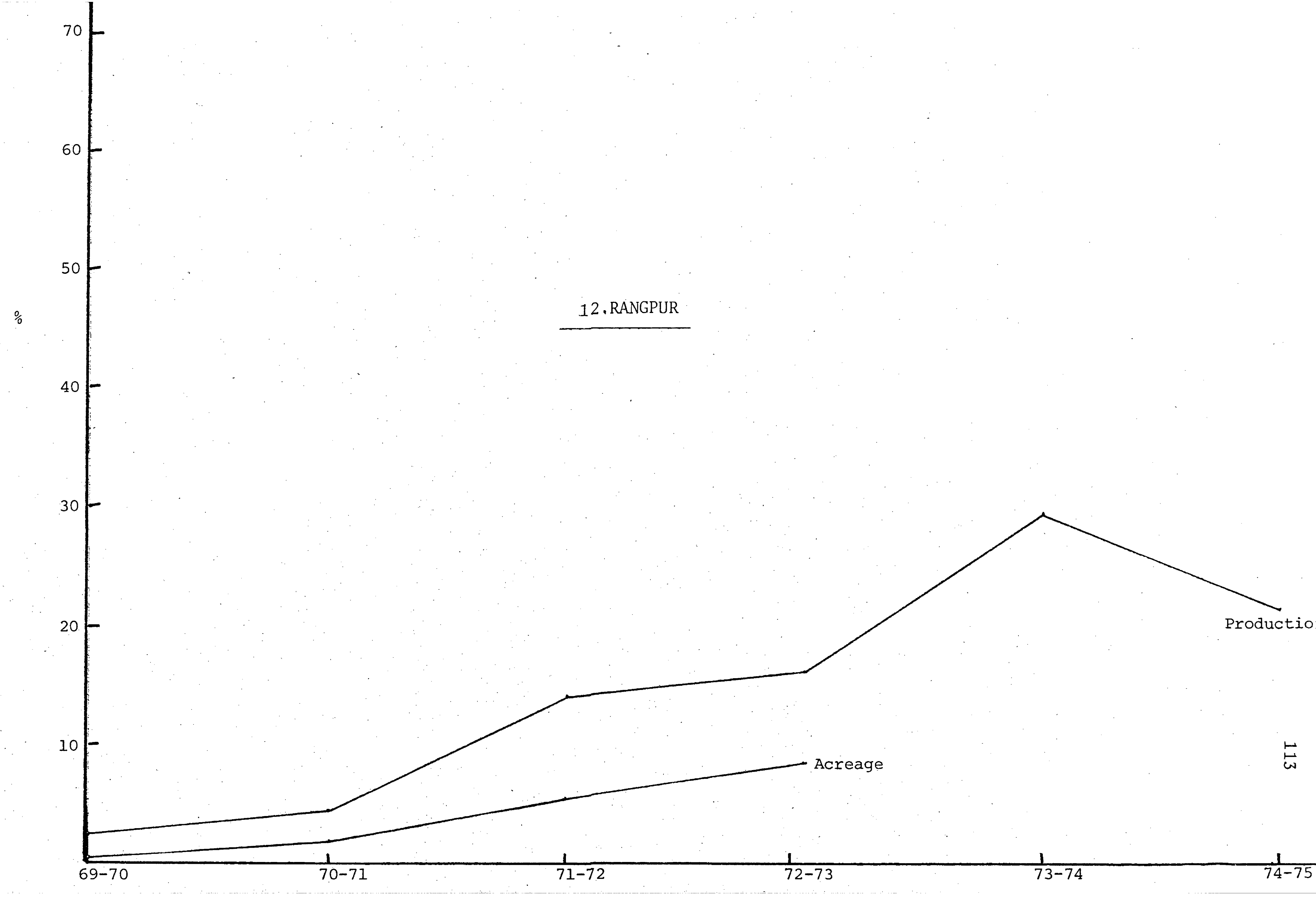
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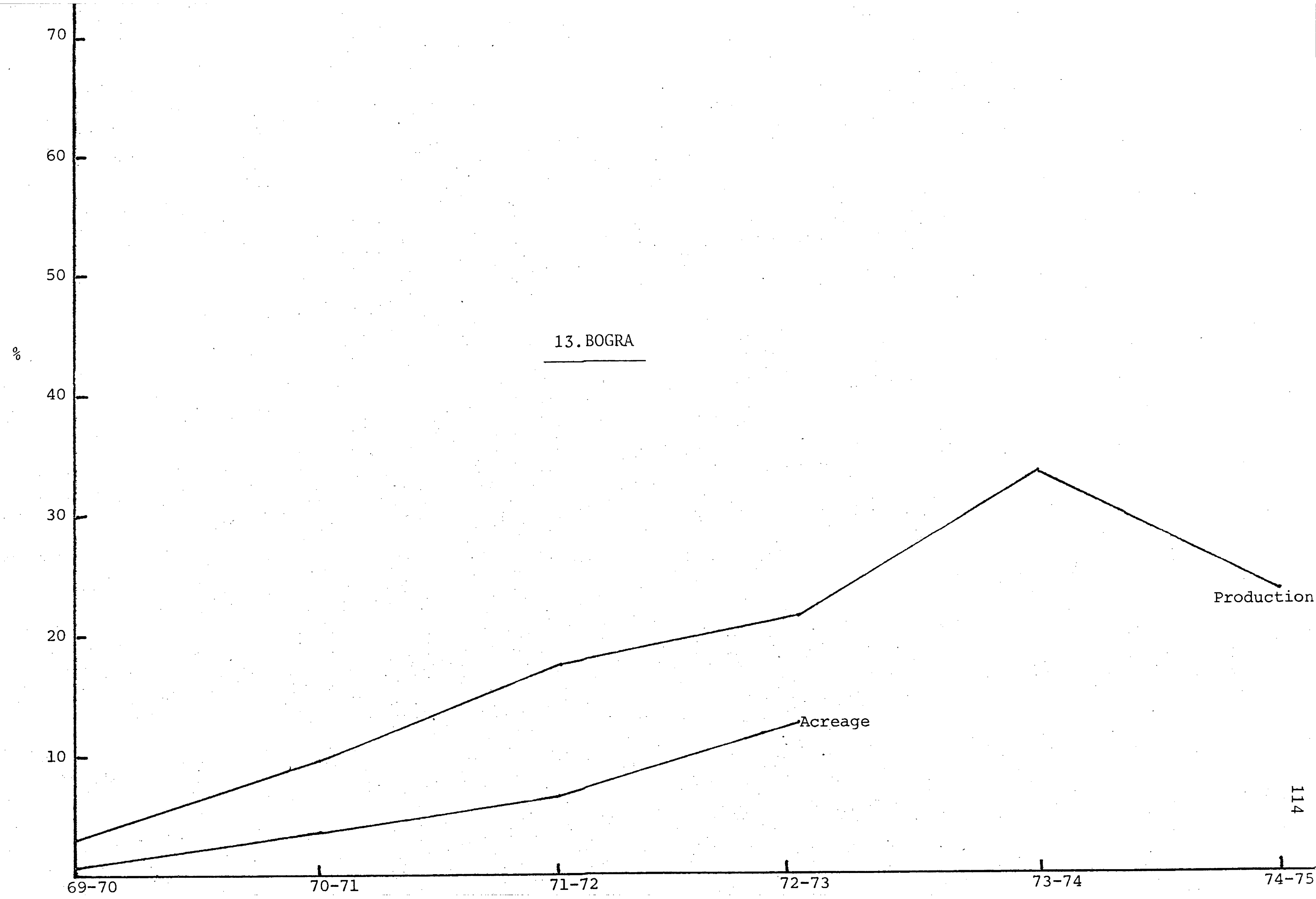
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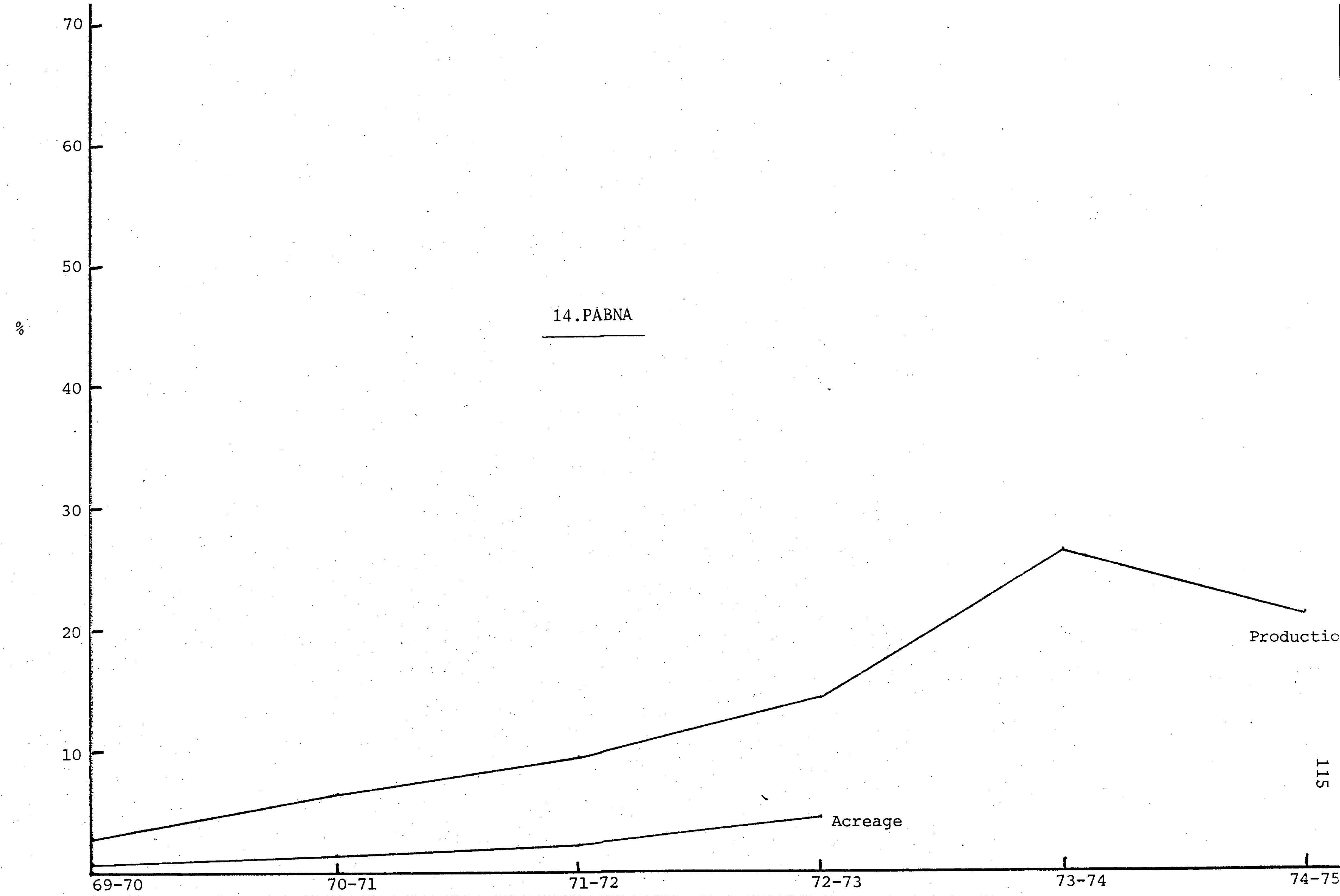
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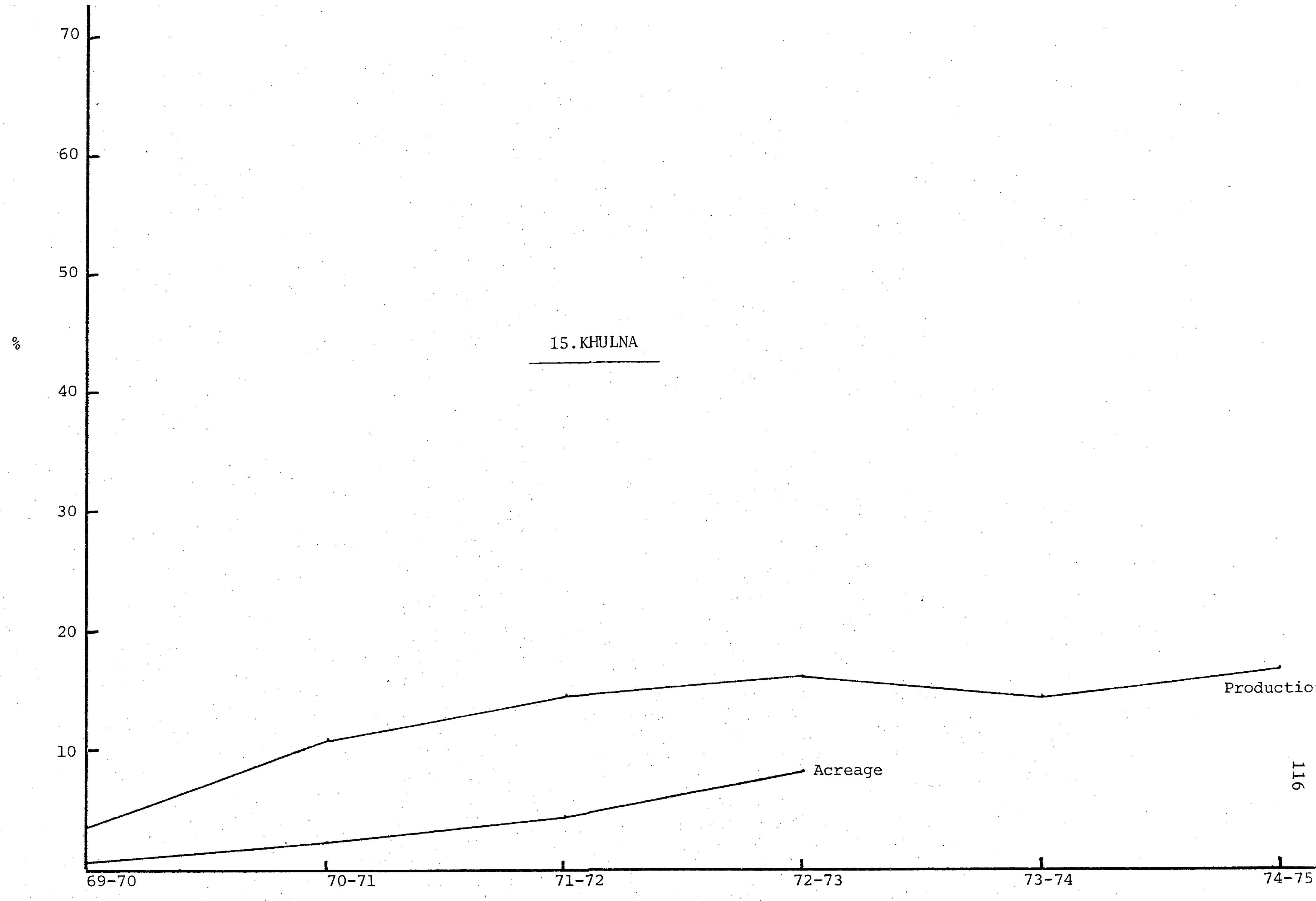
15. KHULNA



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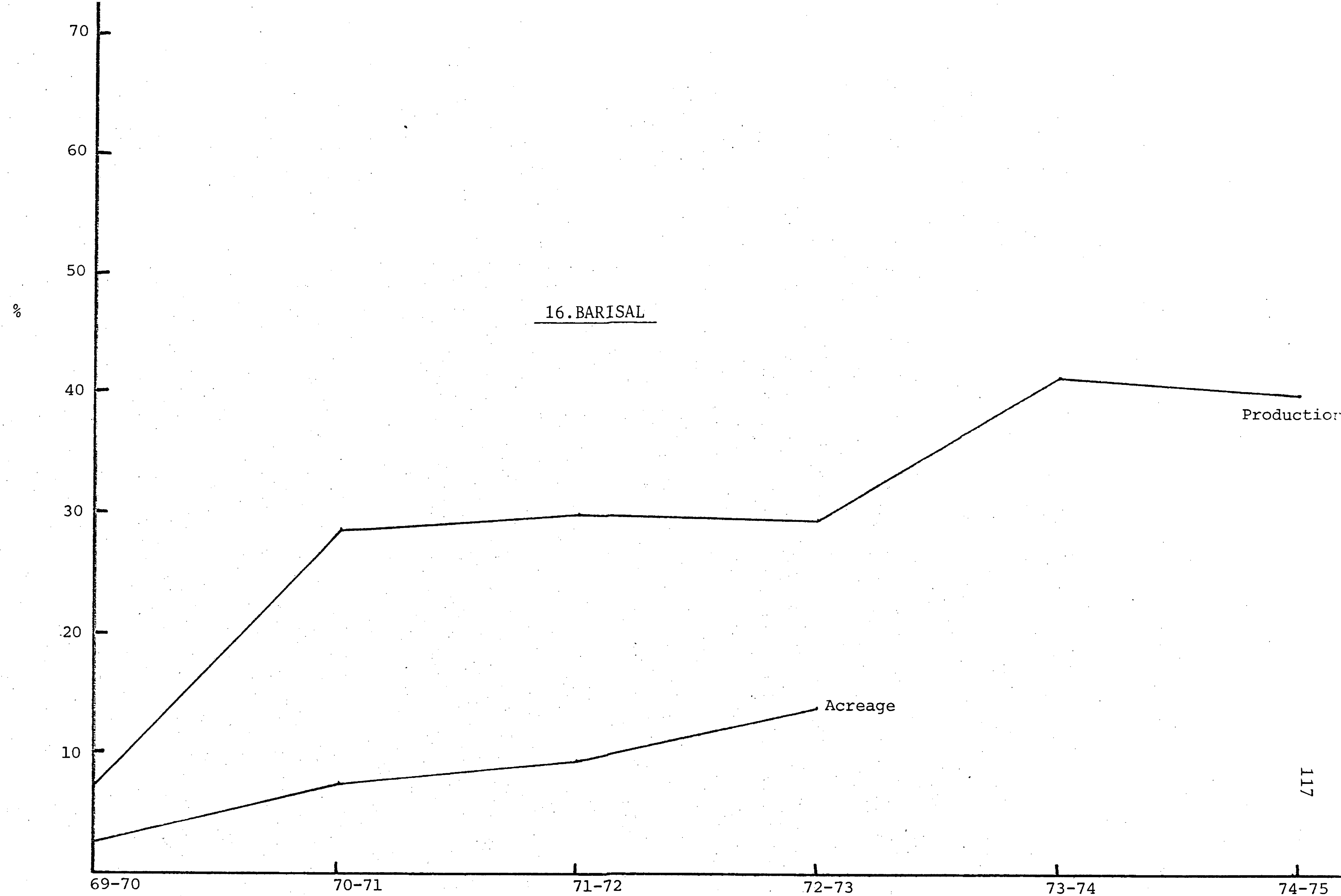
16.BARISAL
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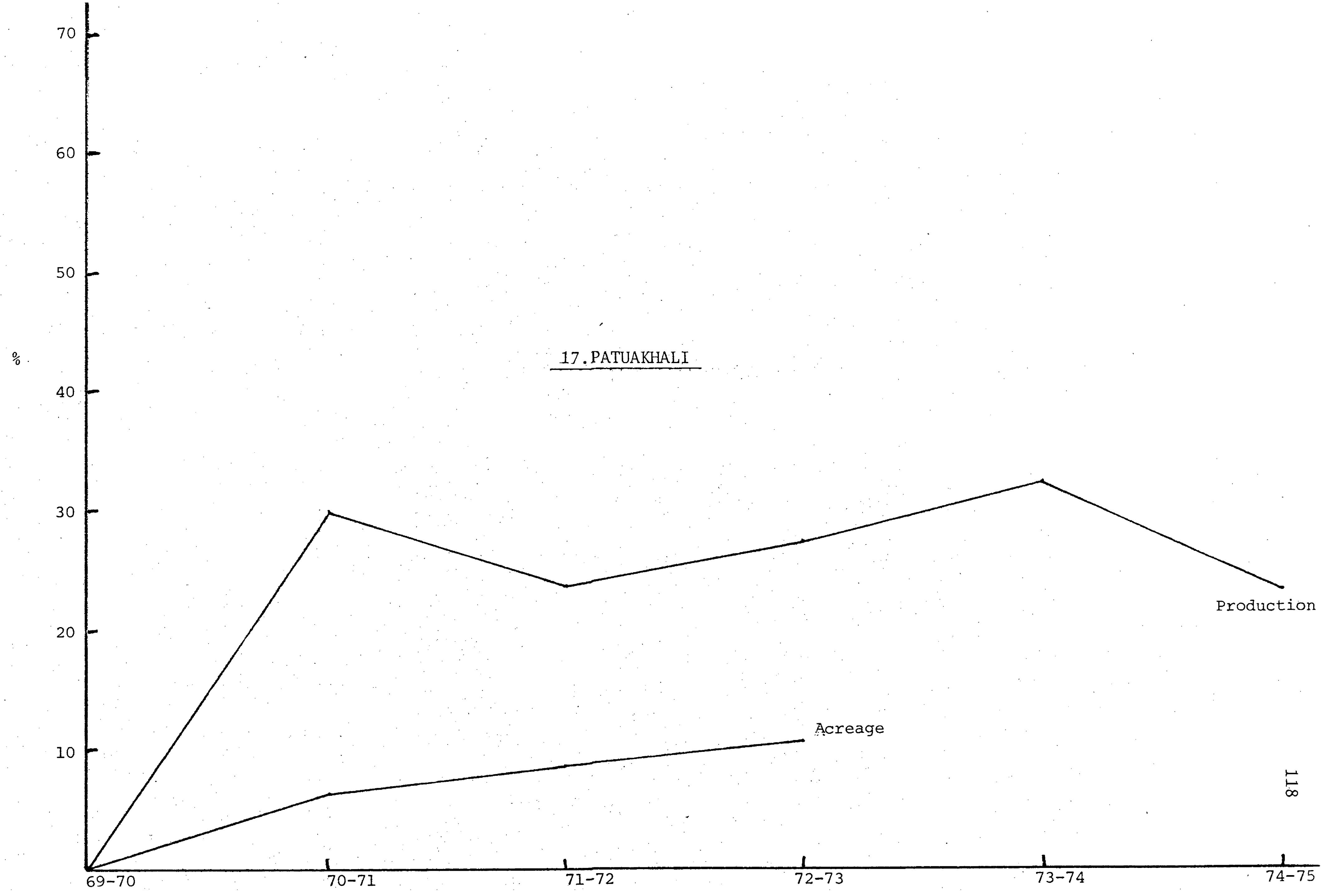
17.PATUAKHALI
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Production
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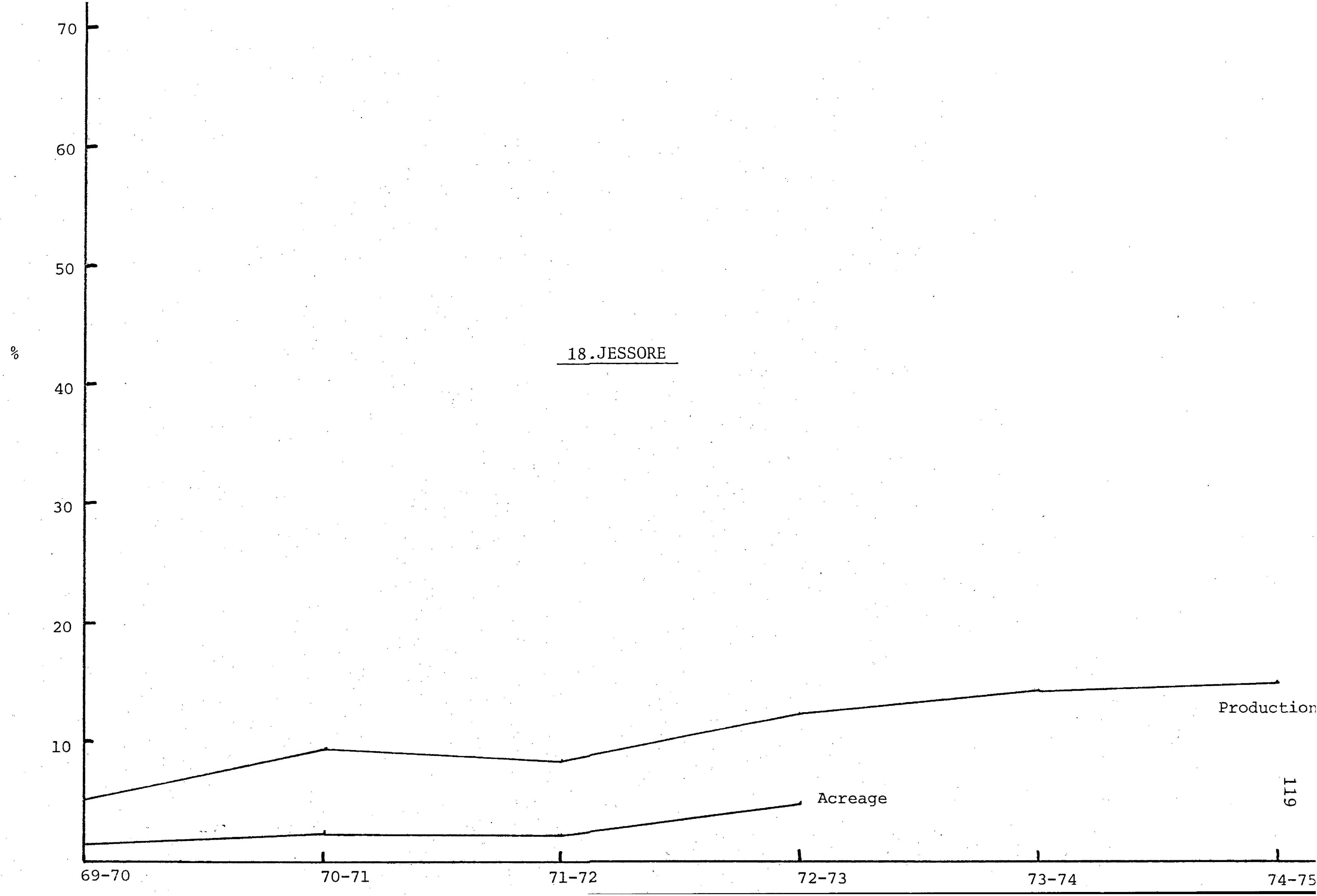
18.JESSORE
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Production
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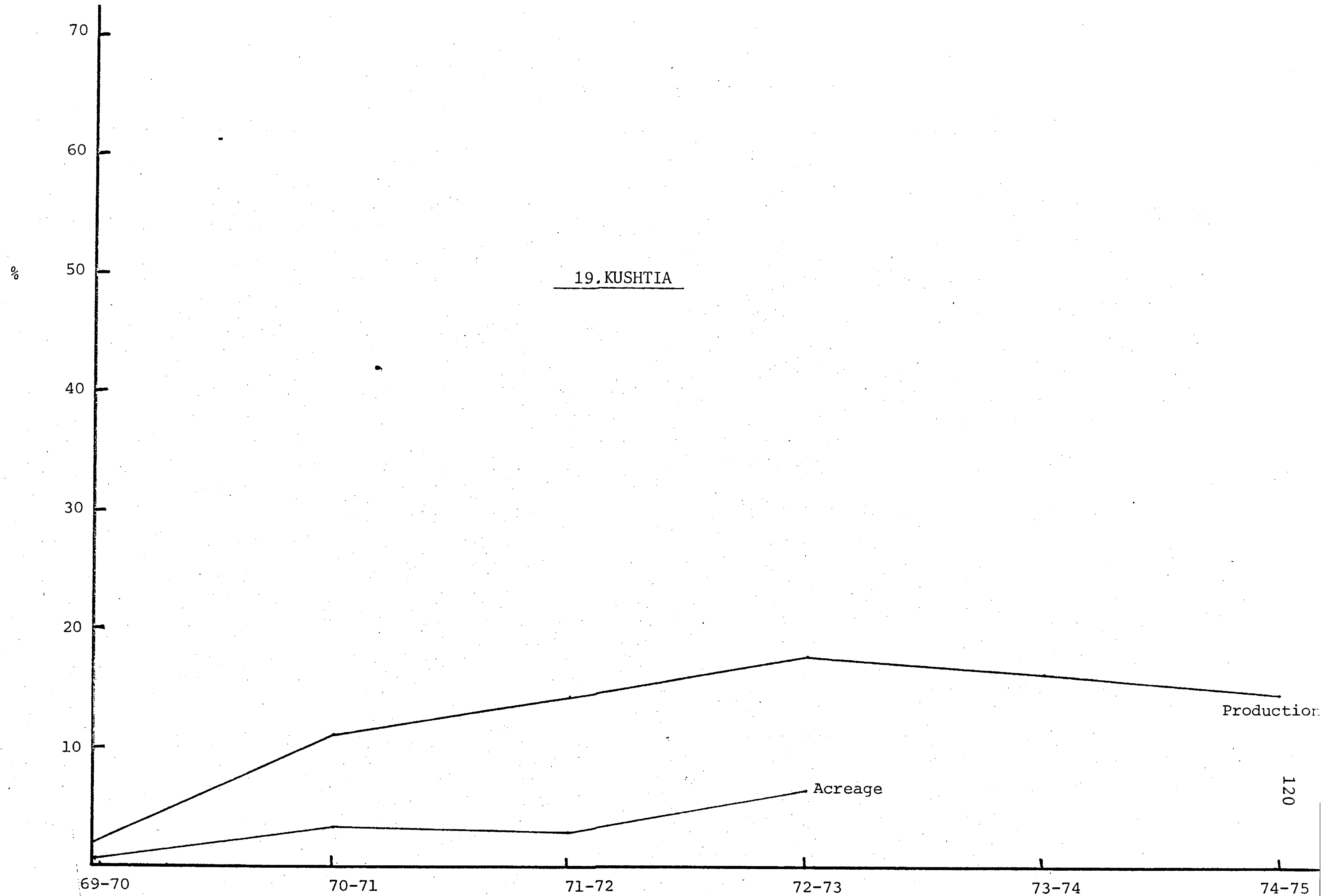
19.KUSHTIA
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Production
Acreage